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COMMODITIES IN DIVERSIFIED PORTFOLIOS

A European Perspective

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Abstract
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Commodities in diversified portfolios: a European perspective

Purpose of the study

Commodities have long been neglected by financial investors, mostly due to their notoriously high volatility. Just now, commodities are about to enter into the mainstream of asset management and assets are piling into commodity-linked funds, products, and indices. The objective of this study is to assess the attractiveness of commodity investments from the viewpoint of a European portfolio investor. The paper reviews the return characteristics of commodities, and analyses the diversification benefits available from adding commodity futures into a portfolio consisting of stocks and bonds.

Data

The overall commodity market is proxied by the Goldman Sachs Commodity Index (GSCI). In addition, five Goldman Sachs commodity sector indices are used: energy, industrial metals, agricultural products, livestock, and precious metals. Furthermore, a selection of individual commodity futures contracts underlying the sector indices is utilised. Equity returns are proxied by the MSCI Europe total return index, and bond returns by the redemption yield of German 10-year government bond. One-year German euro/mark rate is used as the risk-free rate of return. USD-denominated data is converted to euros with a synthetic EUR/USD time series dataset.

Methods

Characteristics of commodity returns are analysed by calculating returns and cross-asset correlations across business cycles and asset classes. Asset allocation and performance measurement of portfolios is conducted using the Stutzer index and the Omega measure.

Results

Correlation of commodities with stocks and bonds has been very low, even negative for some commodity sectors. Commodities have also possessed counter-cyclical properties in comparison to the traditional corporate securities and displayed potential to act as an inflation hedge to some degree. Allocation of commodities into a diversified portfolio improves the risk-return profile of the portfolio. Already a moderate ten percent allocation has the desired effect. An optimal commodity portfolio consists of energy, industrial metal, and livestock futures.

Keywords

Commodity investing, portfolio diversification, performance measurement, asset allocation

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1. Introduction

> The Harvard University Endowment, a bellwether for many as an indicator of progressive thinking in institutional portfolio management, is widely cited as one investor bullish on commodities. Accordingly, it has 13% of its funds in the sector: that's just under $3 billion of its $22.6 billion endowment. … Its stake in the asset class is an important testament to the growing interest in the sector.[1]

> Cash invested in commodity indexes has reached around $50 billion, a rise of about 900% over the past five years. … Most of that cash has come from institutional investors looking to diversify away from equity and bonds amid sluggish returns in those markets over the past few years. More recently, retail investors have taken a strong interest in the commodity markets, encouraged by record high oil prices and a growing recognition of the benefits of diversification.[2]

1.1. Background and motivation of the study

As the opening quotes demonstrate, commodities are about to enter into the mainstream of portfolio management. The phenomenon, however, is very recent. The asset class has long been neglected by financial investors, mostly due to the notoriously high volatilities of many commodities, such as crude oil, the front page celebrity of business newspapers all over the world. Commodities as portfolio investments have been until very recently largely ignored by the academic community as well. Research papers dating as close as 2004 would cite commodities as "a relatively unknown asset class" (Gorton and Rouwenhorst, 2004) or as historically "inappropriate investments because of their perceived risky character" (Vrugt et al., 2004). At the moment, however, billions of dollars are flowing into commodity investments and the asset class has begun to grab headlines in mainstream business newspapers. What is there behind the daze?

The ultimate goal of any portfolio manager is to achieve as high returns as possible per unit of risk taken. The markets for traditional corporate securities, such as stocks and bonds, are becoming increasingly correlated due to the global integration of financial markets and the

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[1] Quote from Rian P. Akey, Cole Partners, Chicago, USA. Appeared on a working paper draft "Commodities: a Case for Active Management" dated February 4, 2005.
[2] Quote from Patrick Fletcher in his article "Buying into commodities", Risk magazine, May 2005.

industrial sectors in which the corporations issuing the securities operate. The increasing correlations make that diversification possibilities available from stocks and bonds are becoming more and more limited. Uniquely among asset classes, commodities are claimed to offer uncorrelated investment opportunities. Furthermore, the possibilities exist across individual commodity sectors whose underlying fundamentals driving the returns differ significantly. This paper probes into the properties of commodity returns using advanced performance metrics and assesses their potential to provide diversification benefits for European portfolio investors.

1.2. Objectives of the study

The main objective of the study is to evaluate the diversification benefits available from commodity investments. The study describes commodities as an asset class and discusses their benefits in portfolio diversification purposes. Relevant topics to be covered are e.g. the mechanics of the determination of returns on commodity futures and the differences between commodities and corporate securities as financial investments. The empirical part of the study analyses the characteristics of commodity returns from the viewpoint of a European portfolio investor. The main research questions can be summarised as follows.

- Does an allocation to commodities improve the risk-adjusted performance of an investment portfolio consisting mainly of traditional corporate securities?
- What kinds of factors are driving the returns on commodity futures and how do they behave in comparison to stocks and bonds?
- Which commodities serve the diversification purposes the best?
- How large an allocation is sufficient to deliver the desired diversification benefits?

The study is limited to the level of strategic asset allocation. A stance is taken only towards the feasibility of a static allocation to commodity futures. The commodity returns discussed in the paper are always those available from holding long positions in nearby futures contracts and rolling the forward monthly[3]. Hence, empirical analysis of the term structures of commodity futures, timing of trades, trading strategies, and active asset allocation decisions are outside the scope of the empirical study.

1.3. Contribution of the study

The paper in hand contributes to the existing literature in two ways:

i) by analysing commodity investments from the viewpoint of a European investor with a euro-denominated portfolio exposed to European equity and bond markets, and

ii) by utilising advanced performance metrics that take into account the non-normality of commodity returns.

Both the above mentioned aspects have so far been absent from the academic research on commodities as financial investments, a field of study that has been covered fairly thinly altogether. Reviewing commodity investments from the European perspective is of special interest as virtually all of the research to date has been conducted in the context of American investment portfolios. Vast majority of the commodity markets available to financial investors are US-traded. Hence, despite many commodity markets are fairly integrated globally, the futures prices of US-traded commodities can be expected to be subject to changes in the macroeconomic variables of the US economy. Furthermore, when added to a portfolio exposed to European equity and bond markets, US-traded commodity futures combine with securities subject to European business cycles. Hence, the potential diversification benefits of commodity futures might prove fundamentally different than the empirical evidence drawn from the US studies would suggest. The need to assess commodity investments from viewpoints other than merely the American one has been explicitly brought up by e.g. Gorton and Rouwenhorst (2004).

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[3] Rolling forward futures means simply selling the contracts before maturity and buying the next ones to expire.

> The US markets for some commodities … are probably integrated with global markets, but prices of others are likely to be influenced by local conditions …. It is conceivable that a common country-specific US factor has positively influenced both stock and commodity futures returns in the US. If that were the case, commodity futures might look quite different from the perspective of a foreign investor. Therefore, it is interesting to ask whether a Japanese or UK investor would draw the same conclusion as a US investor about the relative performance of these asset classes.

The justification for the second aspect of academic contribution, the employment of alternative performance metrics, stems from the well-known fact that commodity returns are not normally distributed. The conventional performance metrics based on the infamous mean-variance theory, such as the Sharpe ratio, assume that asset returns are normally distributed, and that their risk-adjusted performance can be fully described by the mean and the variance of the return distribution. In cases where asset returns are not normally distributed, usage of conventional performance metrics based on the mean-variance theory may lead to suboptimal asset allocations or to situations where an asset manager can intentionally "game" the applied performance metrics at the cost of investors. The study in hand tackles this problem of performance measurement and asset allocation, taking into account the non-normality in commodity futures returns. Two alternative performance metrics are employed, the Stutzer index (Stutzer, 2000) and the Omega measure (Keating and Shadwick, 2002). Utilisation of the two metrics requires making some behavioural assumptions about investors. As to the Stutzer index, it is assumed that investors choose a portfolio to minimise the chance that returns will fall below a threshold level at some future date. Utilisation of the second metric, the Omega measure, assumes that investors choose a portfolio to maximise the ratio of the expected gains above a threshold level to the expected losses below that threshold level. Both the two metrics are free from assumptions concerning the return distributions and incorporate all of the higher moments of the return distributions in the analysis.

1.4. Limitations of the study

The main limitations of the study are data-related. First, no data for the European corporate bond markets was available to cover an adequate time period[4]. Hence, bond markets are represented in the study only by the ten-year German government bond for which adequately long time series of historical data was available. Second, the time frames of the historical datasets of different commodity indices and futures contracts are not overlapping. For some commodity classes and futures contracts historical time series data is available only for periods too short to yield meaningful results. This problem has been partly circumvented by using the composite Goldman Sachs Commodity Index (GSCI), for which there is a long, backfilled data series available, as a proxy for the overall commodity market when commodity returns are compared to those of other asset classes. Sector-specific commodity indices, provided by Goldman Sachs, are also used to fix the scarcity and paucity of the futures data.

1.5. Structure of the study

The remainder of the paper is organised as follows. Chapter two discusses commodity investments on a fairly practical level: what are the benefits and risks of commodity investments, and what kind of different ways there exist to gain exposure to commodity markets. Chapter three reviews the relevant earlier research and presents the theoretical foundation of commodity futures returns and performance measurement issues. Chapter four sums up the preceding discussion by stating the hypotheses for the empirical part of the study. The data and methods used in the empirical analysis are described in Chapter five. Chapter six discusses the empirical findings and Chapter seven summarises and concludes the paper.

[4] Of the European corporate bond indices, the longest historical time series data is available for the MSCI European Corporate Credit Index (MSCI ECCI), extending only to 1994.

2. Why and how to invest in commodities?

Most of the discussion on commodities, both in the academic community and the financial industry, has revolved around risk management issues. During the recent years, however, commodities have followed other alternative asset classes, such as hedge funds and real estate, into the limelight of the financial world as a potential new asset class to be added to balanced portfolios. This chapter takes a rather practical view to the issue and aims to shed light on the motives, risks, and vehicles of commodity investments.

The ultimate goal for any portfolio manager is to achieve as high returns as possible per unit of risk taken. This cannot be attained by focusing only on maximising the return side of the coin, but by mastering also the risk component of the investment. When investing mainly in traditional corporate securities, most often equities and bonds, controlling the risk might become a problem as the returns of these traditional assets are fairly highly correlated. For example, most US and European equity indices are highly correlated with the world equity market factor. Furthermore, geographical diversification has become more difficult as industrial sectors have become truly global and hence become more correlated across countries. As to the bond markets, the situation would seem largely similar. Most fixed income securities and even the shape of the yield curve are highly correlated to the overall market situation in the US. (See e.g. Till, 2001a for a brief discussion on the issue.)

Commodities represent a unique asset class for diversification purposes and an answer to the portfolio risk management challenge discussed above. The underlying logic for this is the profoundly different nature of commodity assets when compared to corporate securities such as stocks and bonds. Corporate securities represent liabilities of firms and their economic function is to raise capital. Investors bear the risk that the cash flows generated by the firm might be low and very volatile. Essentially, the value of the investments depends on the quality of decisions made by the issuing firm. Commodity futures and the way how their returns are generated are profoundly different from corporate securities. From the industrial companies' perspective, commodity futures represent insurances for the value of their future in- or outputs. The investors and speculators acting in the same commodity futures market then provide these insurances and receive compensation in the form of risk premiums for bearing the short-term risk of commodity price fluctuation that companies are not able to absorb due to the high level of business risk involved. Worth noting is also that commodity futures do not represent exposures to actual commodities. Futures prices represent instead bets on the expected future spot price and their valuation is hence not dependent on the current level of spot prices. Key drivers linking the futures prices and expected future spot prices are the expected availability and inventory conditions of a given commodity.[5]

The brief discussion above illustrates some of the key aspects on why commodity futures investments can effectively be used to improve the risk-return characteristics of an investment portfolio consisting mainly of traditional corporate assets. Weiser (2003) sums up the strategic reasons for commodity investments in three points. First, commodities offer well-established diversification that other asset classes cannot match. Second, long-run commodity returns, driven by real and measurable economic relationships, do not depend on the skills of the asset manager. Third, the returns and liquidity available in the case of commodities are of sufficient magnitude to justify a non-trivial allocation.

In addition to managing a portfolio of commodity futures contracts by themselves, investors are able to gain exposure to the market also by investing in publicly offered commodity funds[6] or in investable commodity indices[7]. The particular type of commodity investing that has made it to the mainstream is the investment in passive, long-only commodity programmes, such as in the GSCI, which is used in this particular study. The mechanics of the index are further discussed in the data description section of the paper. As to the different ways of investing in commodity futures programmes, at least six different ways can be identified[8]:

i. *Implementation via swaps*. Here the investor pays fixed rate, consisting of the risk-free rate and the management fee, to the counterparty institution and receives, or pays, floating according to the percentage gain, or loss, on a commodity index. According to Goldman

[5] An important exception from the rule is electricity which cannot be stored but is purchased only for consumption. This leads to very volatile markets that are subject to seasonal fluctuations. This makes the electricity markets more challenging to model than those for other commodities and largely prevents the use of traditional financial models. Electricity as a commodity, however, is not covered in the study in hand.
[6] For a discussion on commodity funds, see e.g. Elton et al, (1990).
[7] For a general discussion on commodity indices, see e.g. Ranga (2004) or Schneeweis and Spurgin (1997).
[8] Following the presentation of Alexander (2004).

Sachs (GS), this method has proven to be by far the most popular among institutional clients.

ii. *Buying and rolling the underlying futures contracts.* Here the investor replicates the strategy of the index provider by buying futures contracts from various exchanges and then rolling them forward similarly as the index provider does. This is a costly and timely exercise, especially if the investor does not have any commodity-related business otherwise. Accordingly, GS reports that less than 5% of the known GSCI investors choose this method.

iii. *Buying and rolling index futures contracts.* In this case the investor buys futures contracts on the desired index, e.g. GSCI futures are quoted on the Chicago Mercantile Exchange, and rolls them forward similarly as the index provider. This market should be highly efficient as it is arbitrageable, and also arbitraged, versus all the underlying markets. According to GS, this method is most favoured by the largest asset managers.

iv. *Third party asset managers.* The portfolio managed by a third party is a semi-passive one: in addition to a strategy similar to the one described in the third method, the portfolio manager can manage some degree of tracking error in order to reduce transaction costs and to actively manage cash in a short-duration fixed income portfolio in order to create excess return.

v. *Implementation via structured notes.* Here investor buys notes or bonds issued by a third party where the returns on the bonds are linked to the performance of a commodity index through index futures. In this case the risk profile of the investment can be tailored to suit the investor. However, in this case the value of the investment fluctuates with volatility and interest rates.

vi. *Implementation via certificates.* These certificates are securities that track the value of an underlying commodity index. The issuing institution charges a management fee reflecting the bid/ask spread the institution incurs when rolling the underlying futures contracts. According to GS, this is the simplest way to gain direct exposure to the index on an unleveraged basis.

Obviously, an investor could set up his own commodity futures portfolio and begin trading independently in the market. This, however, is an extremely costly operation requiring considerable expertise. Hence, this option is hardly viable if the investor does not have any commodity trading -related operations already set up.

Finally, we briefly discuss the main risks associated to commodity investing. Based on the discussion so far, commodities would seem an ideal investment: potential to systematic excess returns, low correlations with other asset classes and even potential to hedge inflation risk. Like with any financial instruments, risk accompanies investments in commodity futures. Till and Eagleeye (2004) make an overview to the risks involved in commodity investing. They list both the idiosyncratic risk factors of commodities and the most relevant systematic macroeconomic risks. As to the commodity-specific idiosyncratic risks, the authors recognise four main sources of risk.

i. *Commodity returns are time-varying.* Commodity investments should be made at times when inventory levels are low and when the futures market is in backwardation[9]. Timing of the investment creates hence the risk.

ii. *Extreme volatility during low inventory levels.* During times of inadequate inventories, price is the only component of the pricing complex that can balance supply and demand. This may cause explosive behaviour of prices.

iii. *Correlations amongst commodity markets may vary seasonally.* At times seemingly unrelated commodity markets can become highly correlated. In such a case, the risk of a particular commodity strategy might double from the original level of risk envisaged when designing the portfolio allocation.

iv. *Structural changes in the commodity markets may adversely impact the returns.* An important driver for returns available from holding long positions in commodity futures is the risk premium, in the form of which the short-term price risk of a given commodity is

[9] The term backwardation refers to the situation in futures markets when the futures price of a given commodity is below the spot price i.e. the term structure of a particular commodity futures contract is declining. The concept will be discussed in more detail in the next chapter.

transferred from industrial players to financial investors[10]. Changes in the organisation of the production of a given commodity could reverse the setting.

When considering an allocation to commodity futures, the potentially unstable nature of the intra-commodity correlations is of particular interest to a portfolio investor. Appendix 2 illustrates the correlations between eleven selected commodity futures contracts that are included in the GSCI over six five-year periods between 1974 and 2004. A quick examination of the tables shows that correlations between individual commodities have varied significantly over the examination period. For example, the changes in correlations between wheat, sugar, and coffee, all included in the Goldman Sachs sector index for agricultural products, have been under constant change. Appendix 3 gives three more case examples of different types of changes in intra-commodity correlations.

In addition to the idiosyncratic risks of commodity investments described above, the macroeconomic environment plays a key role in determining commodity returns. According to Till and Eagleeye (2004), the most important factors are the inflationary and interest-rate environments.

Now that we have made a review of the most important motives, risks, and ways to invest in commodities, we will turn into looking at the academic side of the issue by reviewing the related theory and previous research.

[10] This transfer of risk will be discussed in more detail later in the next chapter.

3. Commodity investments: related theory and research

The review of underlying theory, market mechanics and related earlier literature in this chapter will concentrate on topics that are relevant from the viewpoint of an investor regarding commodities as a means of balancing the investment portfolio and providing better risk-adjusted returns. The topics include the characteristics of commodity returns and their differences from those of traditional corporate securities, the factors driving the returns on commodity futures, and issues concerning performance measurement of commodity investments, bearing in mind the commodity-specific features. The topics are discussed from the viewpoint of a portfolio investor, and hence issues such as price determination, predictive value of futures prices, risk premia etc., often dominating the discussion on commodity futures, are considered being outside the scope of the study in hand and are hence ignored. Furthermore, the focus is kept on fairly recent research.

3.1. Correlations of commodities with traditional assets and inflation

According to the modern portfolio theory, the risk-adjusted return of a portfolio can be improved by adding assets with low or negative correlations with other assets. The prominent justification for adding commodities into investment portfolios has most often claimed to be their low correlations with other asset classes. What is more, commodities are often cited to provide an inflation hedge. The intuitive explanation for these benefits is that unexpected rises in commodity prices augment the inflation rate and dampen the demand for other assets hence causing downward pressure to their prices.

The diversification benefits of adding commodities into investment portfolios have also been empirically reported. A few American studies have examined the correlations of commodities with other, more traditional, asset classes and concluded in favour of low or negative correlations.[11] Furthermore, there exists a fairly widespread understanding that commodities would have ability to offer inflation hedge.

[11] For a relatively recent and broad discussion on returns and correlations of different asset classes, see e.g. Reilly & Wright (2004).

As to the correlation of commodity returns with those of US equities and bonds, the empirical evidence for low or negative correlations seems fairly solid. Ankrim and Hensel (1993) report negative correlations for the GSCI and the Intermarket Management's Investable Commodity Index (ICI) with both equity and bond markets, represented by the S&P 500 and the Ibbotson Intermediate Government Bond Series indices during the time period 1972-1990. Reilly and Wright (2004), who perform a broad review of correlations across asset classes for the time period 1980-2001, report also negative correlations for the GSCI and the Lehman Brothers Government Bond Index. The correlation with S&P 500 for the time period, however, is reported to be slightly positive the energy sub-index being the only component with a negative correlation coefficient.

Among the more recent literature, e.g. Gorton and Rouwenhorst (2004), Schneeweis et al. (2002), Jensen (2002), Greer (2000), Anson (1999), as well as Kaplan and Lummer (1998) all conclude in favour of commodities improving the risk-return characteristics of a US portfolio consisting of traditional assets through negative or low correlations with other assets. Interestingly, Gorton and Rouwenhorst also report that the diversification benefits of commodities increase with the investment horizon and are pronounced when the equity markets are performing poorly. Similar evidence of the correlations varying according to the phase of the business cycle is provided by Edwards and Caglayan (2001) who distinguish between up and down equity markets and report that the correlations of commodities with stocks are especially low during bear markets. Some authors have also compared the diversification benefits of active and passive commodity investment strategies and ended up favouring the active over the passive ones. Examples of recent studies that demonstrate the benefits of active strategies are e.g. Cerrahoglu (2004) and Jensen (2002).

The ability of commodities to offer an inflation hedge has been one of the most cited justifications for their allocation in a portfolio consisting of equities and bonds. Bonds, being nominally denominated assets and their yields being set by investors requiring compensation for the anticipated inflation, are poorly protected from inflation. Stocks should theoretically offer better hedge against inflation as they are claims for real assets. The companies issuing shares, however, have also nominal obligations to their employees, suppliers etc. which hampers the ability of equity returns to keep pace with the general price level. Commodities instead, being real assets, are claimed to offer superior inflation hedge. First, as commodity futures represent bets on commodity spot prices they are directly linked to the components of inflation. Second, because futures prices convey information about foreseeable trends in commodity prices, they move together with the unexpected deviations from components of inflation (Gorton and Rouwenhorst, 2004). From a portfolio manager's viewpoint this is a crucial feature as the investors are interested in real rather than nominal returns on their investment.

The positive correlation of commodity returns with inflation rate has also been empirically documented by certain US studies. The ability of commodity futures to serve as an inflation hedge was reported already by Bodie and Rosansky (1980) over the period 1950 – 1976. The positive correlation seems to have persisted over time as Gorton and Rouwenhorst (2004) report positive correlation for an equally-weighted portfolio of commodity futures for the time period July 1959 – March 2004. In their study the positive correlation was noted to be the stronger the longer the investment horizon. This is most probably due to the fact that the relation between inflation and commodity returns is a volatile one and hence better captured during longer time periods. The authors also employ a model of expected inflation and extend the examination to unexpected inflation and changes in the expected inflation. Three observations stand out from their study.

i) The negative sensitivities of stocks and bonds to inflation stem mainly from changes in the unexpected inflation.

ii) Commodity futures are also more sensitive to the unexpected inflation but to the opposite direction than stocks and bonds.

iii) Stock and bond returns are negatively influenced by revisions about future expected inflation. Revisions about future inflationary expectations have a positive influence on commodity futures returns.

It clearly seems to be that the ability of commodities to act as an inflation hedge stems from the different behaviour of commodity returns in relation to unexpected changes in inflation as opposed to stock returns. In addition to the results of Gorton and Rouwenhorst presented above, the positive correlation of commodity returns with unexpected inflation has been documented by

Ankrim and Hensel (1993) and Erb and Harvey (2005). Further, Kaplan and Lummer (1998), who perform a year-by-year analysis of the GSCI returns, found out that returns on the GSCI futures were pronounced during periods of high inflation. What is more, in a high-inflation environment, the returns on the GSCI were especially high when inflation was increasing. Froot (1995) regressed the excess return on a diversified portfolio to return series of several real assets and concluded that commodities, represented by the GSCI and crude oil, can act as a better inflation hedging vehicles than the inflation itself[12]. In practice this means that returns on stocks and bonds can be negatively affected by changes in commodity prices that are not related to the measures of CPI inflation.

Finally, it should be noted that the sensitivities to inflation vary across different commodities, as reported by Erb and Harvey (2005). Indeed, they found out that not all commodities are good inflation hedges. Three commodity sectors (energy, livestock, and industrial metals) and three individual commodity futures (heating oil, cattle, and copper), had positive and statistically significant inflation betas[13]. Further, they found out that the unexpected inflation betas were explained by the roll returns of the futures contracts. Average roll returns had been highly correlated with the unexpected inflation betas. In other words, the same futures contracts through which price risk had been transferred in the market the most[14] would have been the best hedges against inflation. The three commodities mentioned above as effective inflation hedges can all be regarded as commodities that are difficult to store. Hence, storability could be the link between the roll returns of commodity futures and their ability to act as an inflation hedge. Prices of commodities that are difficult to store tend to be subject to high volatility as price has to do all the work to balance supply and demand in the market. It might be that price shocks of this kind of commodities have the strongest adverse effects on stock and bond returns. In this case, long positions in commodities with difficult storage conditions would be the most effective hedges for portfolios containing stocks and bonds.

In conclusion, the empirical evidence on the diversification benefits of commodities clearly favours allocation of commodity futures into a portfolio consisting of traditional corporate

[12] Refers to the use of inflation-linked notes as a hedging tool.

[13] Erb and Harvey regressed returns on commodity futures to actual and unexpected inflation. Unexpected inflation was proxied by changes in the actual inflation. Beta refers to the regression coefficient.

[14] The linkage between roll returns and transfer of price risk of a given commodity will be discussed in detail in the next section.

securities. All of the above mentioned papers, however, have been conducted from the viewpoint of an American investor with US data. It is possible that there has been a country-specific US factor that has affected the returns of stocks, bonds, and commodities as well as the rate of inflation. Therefore, it could be that a European investor would not draw the same conclusions as his American counterpart would. There clearly exists need to study the diversification benefits of commodities from the viewpoint of a European investor. This has also been brought up by Gorton and Rouwenhorst (2004) in their fairly recent study on commodity investing.

3.2. *Determinants of commodity futures returns*

As already mentioned earlier in the paper, commodity investments are generally not made through exposure to physical commodities. In this case the returns on commodity investments would be driven by solely by the spot market. Instead, commodity investments are made through futures markets by taking long or short positions in commodity futures contracts. The variation of the spot price is only one of the many determinants of the futures prices. Generally, returns of commodity futures can be expected to be higher than those of physical commodities traded on the spot market. The determinants of the futures returns and their differences from the spot prices are discussed below.

It has been argued that there are systematic positive returns available in the commodity futures markets (see e.g. Till, 2000). The possibility for generating systematic returns stems from the fact that many commodities are difficult or even impossible to store. Due to difficult storage situations, the price has to do virtually all of the work of balancing supply and demand in the market, leading to very volatile spot commodity prices. The long lead time between the production decisions and the delivery of many commodities even adds to the volatility. Industrial companies and holders of commodity inventories will then go to the commodity futures markets in order to control the price risk inherent in their business. The price pressure resulting from this commercial hedging activity causes a commodity's futures price to become biased downward (upward) relative to its expected future spot price. Hence, by taking long (short) positions in the opposite leg of commodity futures contracts than the hedgers, an investor is able to earn a risk premium. Chang (1985) defines the risk premium as follows.

The term 'risk premium' generally refers to an average reward to investors for being willing to assume a risk position in a risk-averse financial world. The reward in this form should not be conditioned on any superior judgement or inside information.

The phenomenon of futures prices being below expected spot prices is referred to as the concept of normal backwardation originally envisioned by Keynes (1930). In his famous study, Keynes described a world in which commodity producers use futures markets to transfer the price risk to speculators who are risk averse. In order to compensate the speculators, hedgers agree to set the futures price below the expected spot price. Hence, the futures price is expected to appreciate over time as it converges with the spot price at the maturity of the contract. In the opposite case where futures prices are above the expected spot price the markets are said to be in normal contango. These cases in the sense of Keynes are by definition different from backwardation and contango (not normal) where futures prices are compared to current spot prices. Even if the two concepts are often used interchangeably by the industry practitioners, risk premiums exist only in the case of normal backwardation as defined by Keynes. In an efficient market, keeping long positions in contracts that trade below the current spot, hence being in backwardation, should not yield economically abnormal profits.[15]

The concepts of normal backwardation and normal contango have also been empirically tested. Early tests on normal backwardation considered whether hedgers had in aggregate short or long positions. Normal backwardation would under this interpretation exist if speculators generated profits. Houthakker (1957) tested this hypothesis by studying returns on both long and short positions of speculators that hold positions complementary to large hedgers. Houthakker found evidence for normal backwardation in cotton, wheat, and corn futures. Later studies on the issue have concentrated on examining the risk premiums of commodity futures prices. Kolb (1992) studied 29 commodities during the period 1959 – 1988 and concluded that only seven of those exhibited evidence of risk premium. Three of the seven contracts were in contango (heating oil, crude oil, and lumber) and four in backwardation (live cattle, feeder cattle, live hogs, and orange

[15] Normal backwardation can be formally expressed in the form of rollover gains from holding long positions in futures contracts and rolling them forward before maturity. The rollover can be decomposed as follows: $f_t(0) - f_t(1) = s_t - E_t s_{t+1} - p_t(1)$ where $p_t(1)$ is the risk premium attached to the nearby futures contract. A negative premium would indicate normal backwardation whereas positive premium indicates normal contango.

juice)[16]. Deaves and Krinsky (1995) revisit the same 29 contracts, add five years of data and conclude similarly to Kolb. The conclusions of the two above mentioned papers seem to be in line with the intuitive notion that the commodities in case of which the speculators are compensated for the risk transfer are those who are difficult, expensive, or even impossible to store.

Much of the recent academic discussion on the predictability and efficiency of commodity futures prices has concentrated on energy contracts. This is mostly due to the economic importance of energy markets which account for a large part of the open interest in commodity futures markets. What is more, energy markets often exhibit very high volatility. It can also be often observed, especially in the case of oil markets, that the futures prices trade below the current spot price. Litzemberger and Rabinowitz (1995) study backwardation in oil futures markets during the time period 1984 – 1992 and conclude in favour of backwardation[17]. The paper of Litzemberger and Rabinowitz is of special interest as they introduce uncertainty to their model by treating oil reserves as call options. Their empirical evidence suggests that backwardation in oil futures markets is directly related to implied volatility. Charupat and Deaves (2002) calculate rollover gains for energy futures contracts[18] for the time period January 1984 – December 2000 in order to gain understanding on the degree of backwardation or contango in the market. They find that the rollover gains are on average positive and hence report that the three energy markets have hence exhibited backwardation. However, no empirical support is found for normal backwardation[19]. Theoretically, persistent backwardation requires existence of normal backwardation[20] and the results obtained by Charupat and Deaves would hence appear confusing. However, the authors claim that the empirical results are most likely due to the weak power of the statistical tests to fail

[16] Kolb revisits returns on commodity futures in his 1996 paper. The empirical results from an extensive dataset of daily returns showed positive returns for 19 and negative for 14 commodities. This time all energy commodities exhibited positive returns.

[17] Litzemberger and Rabinowitz found evidence of "weak backwardation" which they define as the situation when *discounted* futures prices are below the current spot price.

[18] The data set consists of crude oil, heating oil, and petrol contracts.

[19] In order to test for normal backwardation, the authors calculate returns on holding one-month contracts until maturity instead for rolling them over before maturity.

[20] See Charupat and Deaves (2002) for discussion.

the unbiased expectations hypothesis and conclude in favour of normal backwardation having been the prevalent situation in the energy futures markets.[21]

The relationship between futures prices and the maturity of the futures contracts can be described by the term structure of futures prices. In cases where the market is in backwardation, the term structure of a particular commodity is declining i.e. the longer the maturity of a contract, the lower the price. Maintaining a long position in commodity futures requires the investor to periodically roll forward his position which essentially means selling an expiring contract and buying the next one to expire. If the term structure of the commodity in question is downward sloping i.e. the market is in backwardation, the investor will be rolling from a higher priced contract into a lower priced one and hence will gain a rollover return. In opposite cases where the market is in contango and the term structure of a commodity is upward sloping, the rollover gains could be earned by maintaining a short position in the commodity futures. The term structure of a commodity has been suggested to be the main driver of rollover gains and hence the returns from commodity futures programmes (see e.g. Erb & Harvey, 2005). As mentioned earlier, most of the commodity futures programmes are taking long positions only. The fairly high returns of these passive programmes are often claimed to be due to their heavy allocation into energy commodities which often exhibit backwardation[22] and hence downward sloping term structures.

The above notion of high returns available for commodities with difficult storage conditions brings us to the theories of storage and convenience yield that can be used to explain the term structures of commodity prices, in addition to the risk-transfer arguments discussed above. As we know, holding of storable consumption commodities incurs costs. The classic theory of storage incorporates the storage costs to the futures prices with a simple arbitrage argument.[23] The classic theory of storage cannot, however, explain e.g. the situation when the term structure of a

[21] The returns on holding contracts until maturity (measuring normal backwardation) were on average higher than the rollover gains (measuring backwardation). However, the rollover gains were statistically significantly positive but the returns on contracts were insignificant. This was due to the standard errors of the returns that were over three times those of the rollovers. Rollovers were claimed to exhibit less variability because both components of a rollover are contemporaneous, whereas the returns have one contemporaneous component and one lagged one. Hence, price shocks will have smaller impact on rollover as both components of the difference can adjust to the shock.
[22] E.g. the long-only GSCI index is world production weighted and hence heavily tilted towards energy commodities.
[23] According to the classical arbitrage argument, the futures price of a commodity at time t must satisfy $F_t \leq (S+K)(1+r)^t$, where K is the present value of storage costs. If the futures price F was larger than the right-hand side of the equation, a trader could make a riskless profit by borrowing $S + K$ at the rate r and using the proceeds of the loan to purchase the commodity at spot S, sell forward for F, and gain a profit at maturity.

commodity is downward sloping i.e. when the market is in backwardation. In such a case, the classic theory of storage would require the storage cost to be negative, a case which is logically impossible. Working (1934) and Hoss and Working (1983) were the first to give a partial answer to the dilemma, demonstrating that that storage costs cannot be considered as fixed, but that they depend on the level of stocks. The conflict between empirical observations on commodity prices and the theory of storage was finally addressed by Kaldor (1939) with his concept of convenience yield.[24] With convenience yield it is referred to the advantages that come in the form of planning benefits of having a secure supply and elimination of costs associated with stock outs, or avoiding stock outs at times when they might occur. The convenience yield hence reflects the market's expectations about the future availability of the commodity. The greater the possibility that stock outs may occur, the higher the convenience yield. When stocks are high and also expected to remain so, convenience yields are low. The other way round, when stocks are low or expected to get very low, convenience yields rise. Convenience yields rising above the storage costs can push the futures price of a commodity below the spot and hence turn the market into backwardation. During the 1990 crisis at the Gulf of Persia, for example, the spot price of crude oil rose to over $40 per barrel while the futures prices stood at around $24 per barred.[25] Such a deep backwardation could hardly be explained by any other theory than the convenience yield. For commodities with difficult storage conditions, the gains from having an immediate access to stock can be significant. The linkages between storage, convenience yield, and returns on commodity futures have been also empirically reported by e.g. Kolb (1996) who found that the biggest gains from holding long futures positions were obtained with commodities that have difficult storage conditions. Interesting examples on the issue can also be found from Till (2000).

As the above discussion demonstrates, there exists a sound basis for viewing commodity futures as an efficient means to enhance the risk-adjusted performance of a diversified investment portfolio. The low correlations with other asset classes, ability to serve as an inflation hedge, and the possibility to generate systematic returns due to persistent features in the term structure all give grounds for arguing in favour of commodity allocation. Greer (2000) breaks down the total return from an unleveraged commodity index into the following four components:

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[24] Convenience yield y can be formally expressed as follows: $F_0(1+y)^t = (S_0 + K)(1+r)^t$, where K is again the present value of storage cost.

[25] An example from Clark et al., 2001.

i) expected inflation plus real rate of return i.e. the money market component of the collateral deposit,

ii) price uncertainty i.e. the risk premium transferred from hedgers to speculators,

iii) uncorrelated volatility, and

iv) the expectational variance.

The difference between the third and the fourth component is that the third one relates to the expectation that commodity futures prices are not highly correlated with each other. Hence, if these prices move randomly, or even in a mean-reverting manner, a value-weighted composite index of commodity futures can capture excess growth[26] from the asset class. The fourth component instead refers to the low correlation of commodities with other asset classes. The diversification benefit stems from the fact that commodity futures prices would react to a given economic event differently than other assets. In sum, the return of commodity futures programmes comes from three different types of sources: change in the price of the commodity, the rollover gain, and the interest on the collateral. The diversification benefit with respect to other asset classes could be regarded as the fourth source of return.

Even if the fundamental factors of commodity futures markets would support their allocation into diversified portfolios, we still face one more challenge: how to correctly measure the performance of commodity investments and which methods should be used for their allocation? There exist certain commodity-specific factors that make the use of many of the traditional methods questionable. The following chapter will discuss the issues related to performance measurement and allocation techniques of commodities.

[26] The concept of "excess growth" Greer utilises is that of Fernholz and Shay (1982). The quantified "excess growth" can be written $\frac{1}{2}\left(\sum_i \pi_i \sigma_i^2 - \sum_{i,j} \pi_i \pi_j \sigma_{i,j}\right)$, where π is the weight of an asset, σ^2 the variance of asset i, and $\sigma_{i,j}$ the covariance of assets i and j.

3.3. Performance measurement and asset allocation techniques

Contrary to traditional corporate securities, such as stocks and bonds, the return distributions of commodity strategies cannot be assumed to be normal (see e.g. Schmidhuber and Moix, 2001). There exist several empirical studies showing that returns on futures strategies are not normally distributed[27]. The basic reason for this is that due to the economic function of risk transfer that commodity futures are performing their return distributions have option-like, asymmetric profiles. The major implication of this perception in the context of the study at hand is that the widely used and accepted CAPM-based mean-variance framework and performance measures such as the Sharpe ratio are not applicable as they assume returns to be normally distributed. Interestingly, it has also been claimed that portfolio managers can intentionally misuse the conventional performance measures when reporting the performance of instruments whose return distribution they know to be non-normal (see e.g. Spurgin, 2001). For instance, Goetzmann et al. (2002) derive static rules for achieving the maximum Sharpe ratio with two or more options and a continuum of derivative contracts. This strategy has a truncated right tail and an elongated left tail. By undertaking this maximum Sharpe ratio strategy, an investor may be accepting negatively skewed returns in exchange for improving the mean or variance of the investment. The obvious problem of this kind of strategy is that most investors are risk-averse and hence would prefer upside risk and be aversive for downside risk. The finding illustrates well the problem of using metrics assuming normality of returns with commodities that have asymmetric returns distributions.

Despite the fact that commodity investments are coming to the mainstream of financial investment world and that the non-normal characteristics of commodity return distributions are known and widely reported, there has been no significant discussion on the correct performance measures to be used with commodity investments. The application of correct performance measures would, however, be of utmost importance as an increasing number of financial investors are allocating funds into commodity investments. Both the portfolio allocation decisions and the evaluation methods of portfolio managers require up-to-date tools. Contrary to commodities, the recently surged popularity of hedge funds has poised discussion on the correct

[27] Kolb (1996) provides a summary of studies that have concluded in favour of non-normality.

performance measures and asset allocation techniques for hedge funds.[28] Similarly to commodities, distributions of hedge fund returns tend to be asymmetric due to the option-like features of their strategies and hence the problems and requirements for performance measures can be considered fairly similar.

As to the performance measures proposed, many of the alternative metrics are modifications to the conventional CAPM-based Sharpe ratio. Modifications of the infamous metric are proposed by e.g. Johnson et al. (2002b) and Mahdavi (2004). The approach suggested by Johnson et al. uses excess downside deviation as an adjustment to the Sharpe ratio. Their adjusted ratio is defined as the Sharpe ratio that would de implied by the portfolio's observed downside deviation if returns were distributed normally.[29] This adjustment should compensate for distortions arising from non-normality of the returns and essentially translates excess downside deviation into equivalent units of the Sharpe ratio. Mahdavi approaches the adjustment from a different angle. Instead of modifying the Sharpe ratio itself, he introduces a method to transform the return on the asset in question to match the distribution of a chosen benchmark, e.g. a broad equity index. Then the Sharpe ratio is calculated using the adjusted return distribution. Hence, the adjusted Sharpe ratio is directly comparable to that of the chosen benchmark.

The advantage of these metrics is that they are conceptually comparable to the widely accepted Sharpe ratio. However, they possess some significant disadvantages that make their use in the case of commodities doubtful. The major shortfall of Johnson et al.'s model is that it only measures the downside deviation of returns and does not take upside deviation into account at all. This is intuitively in contradiction with the assumption of risk averse investors who prefer upside deviations to downside ones. Mahdavi's solution, instead, is theoretically better but its implementation requires manual regressions of returns against chosen benchmarks and hence significantly limits its flexibility and usability in practice.

[28] For broad discussions on performance measurement of hedge funds and other alternative investments, see e.g Gupta (2003), Till (2001b, 2002a, 2002b), and Bacmann & Scholz (2003).

[29] The modified Sharpe ratio λ can be defined as the solution to the equation $\frac{d^2}{\sigma^2} = (1+\lambda^2)[1-\Phi(\lambda)] - \lambda\phi(\lambda)$ where d is the downside deviation and σ^2 the variance of the asset returns, θ the density function of standard normal distribution and Θ the cumulative density function.

Besides modifications to established concepts, such as the Sharpe ratio, some authors propose solutions that go conceptually quite far away from the traditional performance measures. The common denominator for these concepts is that they attempt to largely rethink the whole framework of performance evaluation. Examples of these alternative solutions are e.g. the Omega measure (Keating and Shadwick, 2002), the gain-loss ratio (Bernardo and Ledoit, 2000), nonlinear correlations with a portfolio of traditional assets (Favre and Galeano, 2002), scenario-driven risk visualisation (Johnson et al., 2002a), conditional value at risk (Agarwal and Naik, 2004) and modified value at risk (Favre and Signer, 2002). The Omega measure of Keating and Shadwick is of special interest and it has also been commented by some academics. The approach of the measure is fairly distinctive. Simply put, the measure splits the return universe into two sub-parts according to a threshold. The Omega measure is defined as the ratio of the gain and loss with respect to the chosen threshold. The undisputable credit of the function proposed by Keating and Shadwick is that it incorporates all of the information provided by the return data and it takes into account all moments in the return distribution[30]. A potential downside of the Omega measure is that the ranking of portfolios or assets based on their Omega measure may vary according to the chosen benchmark (Bacmann and Scholz, 2003). The very same feature can also be regarded as a valuable source of flexibility, as will be noted later on in the paper. A method fairly different from the above mentioned ones is the one proposed by Anson (1999). He approaches the risk from a utility-based angle and examines how investors' risk behaviour affects the portfolio allocation of commodity futures. Specifically, the investment behaviour of risk-averse investors is studied in the context of commodity futures[31]. The author founds that the marginal utility of commodity futures investing is higher, the greater the risk aversion of the investor. The findings of Anson further support the potential of commodity futures as a means to diversify portfolio risk.

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[30] With higher moments it is generally referred to the third and higher moments of a distribution. The most prominent of the higher moments are kurtosis and skewness the latter describing the symmetry/asymmetry of a distribution. The first two moments are mean and standard deviation.

[31] Anson defines an investor's objective function in terms of quadratic utility. The expected utility in his equation may be viewed as the expected return on the portfolio minus a risk penalty. The risk penalty is equal to the risk of the portfolio multiplied by the investor's relative risk aversion. Consequently, the expected utility is a risk-adjusted expected rate of return for the portfolio, where the risk adjustment depends on the level of risk aversion. The major downside of Anson's method is that it assumes a mean-variance framework and hence normally distributed returns.

In addition to the above mentioned metrics, proposed frameworks include e.g. the use of style-based metrics or attempts to fit some known distributions to match those of commodity returns. The common denominator of these metrics is the attempt to capture the true risk of an investment and to give theoretically correct interpretation to the concept of risk-adjusted risk. Further review of these methods, however, is outside the cope of the paper at hand.

The common denominator for many of the above-mentioned approaches is that they are difficult, or even impossible, to be applied to portfolio allocation purposes. This stems from either conceptual complexity of the models or from the fact that the practical applications based on them would require excessive computational time and capacity. The Omega measure proposed by Keating and Shadwick, however, can be regarded as both theoretically viable and practically applicable to serve the purposes of the study at hand. Hence, it is chosen as the second performance metric to be used in this paper. The mechanics of the measure are discussed in more detail in Chapter 5.3.3.

The other model chosen for asset allocation and performance measurement purposes in this paper is the portfolio performance index proposed by Stutzer (2000). The Stutzer index is both theoretically coherent to suit commodity investments and algebraically applicable as the author provides a numerical algorithm. The index has a solid behavioural foundation and it is free from any distribution assumptions as well as unspecified parameters. The basic underlying assumption is that investors aim to minimise the probability that the excess returns over a given threshold, e.g. the risk-free rate, will be negative over a long time horizon. In case of positive excess returns, the probability will decay to zero at an exponential rate. The maximum possible decay rate is defined as the Stutzer measure. An interesting feature of the metric is that when dealing with normally distributed returns, the Stutzer index yields identical allocations with the Sharpe ratio. Hence, it should be intuitively fairly easy to adopt. The only downside of the measure is that it is defined only for cases where the benchmark return is on average lower than those on the portfolio assets. The index is discussed in more detail in Chapter 5.3.2.

This chapter has reviewed the theory and most relevant literature on the central features of commodity futures investments. The low correlations of commodity returns with other asset classes, potential to act as an inflation hedge, and the inherent returns available due to the fundamental nature of the return drivers in the commodity markets all back up the claims to allocate a part of a diversified investment portfolio into commodity futures. However, the performance measurement and asset allocation methods applicable for commodities still pose a challenge. The well known feature of commodity returns being non-normally distributed has not yet been fully addressed by the academia. The commodity literature has so far concentrated mostly on the pricing mechanics of the markets. Modelling of prices, studies on the predictability and efficiency of the markets have also been under scrutiny. Studies form the viewpoint of a portfolio investor have until very recently remained fairly scarce. Finally, the previous research has been purely US-centric. Hence, no direct conclusions for the purposes of a European investor should be draws from the cited studies. It might be, for instance, that the equity, interest rate, and commodity markets have all been affected by the same US-specific factors. This paper aims to fill the two gaps mentioned above: the shortcomings of asset allocation and performance measurement methods and the viewpoint of a European investor.

4. Hypotheses

Drawing on the discussion presented in the previous chapter, and the objectives of the study laid out in the opening chapter of the paper, we now formulate the hypotheses for the empirical part of the study where they are tested from the viewpoint of a European investor, holding a euro-denominated portfolio with European stocks and bonds.

> H1: Commodity returns have low or negative correlations with stocks and bonds. They possess counter-cyclical properties with the two other asset classes. Commodities also provide inflation hedge for the portfolio being positively correlated with the inflation rate.

> H2: The inclusion of commodities into a portfolio consisting of stocks and bonds improves the risk-return profile of the portfolio.

The second hypothesis should be regarded as the main hypothesis of the study, the first one serving as an auxiliary hypothesis on our way to assessing the diversification effects of a commodity allocation in a diversified portfolio.

5. Description of data and methodology

This chapter presents the data and the methods used in the study. Methodologically, the empirical part has two levels. First, an overview of the essential characteristics of commodity returns is made. The descriptive statistics of different commodity classes are compared with those of traditional corporate securities. Besides, the correlations between different asset classes are examined. Second, commodity investments are assessed in the context of portfolio diversification. Stand-alone commodity portfolios are constructed in order to gain understanding on the optimal composition of a commodity portfolio, and the effective diversification benefits available from commodities are evaluated by adding them into a diversified portfolio consisting of stocks and bonds. The portfolio part employs two alternative performance metrics, the Stutzer index and the Omega measure, that are free from any assumptions concerning the return distributions and hence capable of incorporating the higher moments of commodity return distributions that depart from the normality assumption. The conventional Sharpe ratio is utilised at the side of the two above mentioned metrics in order to allow the reader to compare the alternative measures with the conventional mean-variance approach.

5.1. Data

Most of the data used in the study is USD-denominated in origin but has been converted to euros in order to be consistent with the viewpoint of a European investor. The EUR/USD exchange rate time series data before the inception of the common currency has been constructed synthetically. As the risk-free interest rate the study utilises the 12-month German euro/mark rate.

In addition to the commodity, equity, and bond data described below, the study includes time series data of the annualised monthly aggregate inflation rate of the EU15 countries. In addition, the CEPR[32] business cycle dating is utilised in order to analyse the behaviour of commodity returns relative to other asset classes across business cycles. The dating sets the dates for the euro area business cycle. It establishes the chronology of recessions and expansions of the 11 original euro area member countries plus Greece for 1970-1998 and of the euro area as a whole from

[32] Centre for Economic Policy Research

1999 onwards. These indicators should provide proxies accurate enough to model the macroeconomic environment of a European investor. The cycles are defined only until the end of year 2000, due to the ambiguity of the European economy since the beginning of 2001. More information on the CEPR business cycle dating can be found in Appendix 4.

All time series data consists of monthly observations, the observation date being the last trading day of the month or equivalent. All reported returns are annualised monthly returns, if not otherwise mentioned. All returns are continuously compounded. All data has been obtained from the Thomson Financial Datastream, except for the individual commodity futures that have been provided by the Commodity Research Bureau (CRB).[33]

The broad commodity market data consists of the Goldman Sachs Commodity Index (GSCI). The GSCI is a composite index of commodity sector returns, representing an unleveraged, long-only investment in commodity futures that is broadly diversified across the spectrum of commodities. The returns are calculated on a fully-collateralized basis with full reinvestment so that the futures investment is rolled forward from the 5^{th} to the 9^{th} business day of each month. The GSCI is world-production weighted which means that the quantity of each commodity in the index is determined by the average quantity of production in the last five years of available data. Currently, the GSCI contains 24 commodities from all commodity sectors: six energy products, five industrial metals, eight agricultural products, three livestock products, and two precious metals. The dataset used in the study includes also time series data separately for the five subcategories mentioned above. The original dataset consists of daily closing prices throughout the time period 1970 – 2004 from which the monthly returns have been calculated. The table below summarises the composition of the GSCI.[34] There exist other, fairly similar indices, e.g. the Dow Jones-AIG Commodity Index and the Reuters-CRB Futures Price Index. The use of the GSCI is, however, the most natural choice as it represents most of the market value of long open interest in the commodity futures index market. In addition to the composite index data, the study utilises time series data for its five subsections: energy, industrial metals, agricultural products, livestock, and precious metals.

[33] The time series data available for the study can be found summarised in Appendix 1.
[34] All the information concerning the GSCI has been obtained from the Goldman Sachs website on March 30, 2005 (http://www.gs.com/gsci/).

Table 1: Components and weights of the Goldman Sachs Commodity Index

Energy	*74,63 %*	*Agri-cultural*	*11,04 %*	*Industrial metals*	*6,80 %*	*Livestock*	*5,68 %*	*Precious metals*	*1,86 %*
Crude Oil (WTI)	28,79 %	Wheat	2,58 %	Aluminium	2,88 %	Live Cattle	2,83 %	Gold	1,67 %
Brent Crude Oil	14,47 %	Red Wheat	0,95 %	Copper	2,26 %	Feeder Cattle	0,72 %	Silver	0,19 %
Natural Gas	9,60 %	Corn	2,41 %	Lead	0,29 %	Lean Hogs	2,13 %		
Unleaded Gas	8,72 %	Soybeans	1,75 %	Nickel	0,82 %				
Heating Oil	8,33 %	Cotton	1,07 %	Zinc	0,55 %				
Gas Oil	4,72 %	Sugar	1,18 %						
		Coffee	0,87 %						
		Cocoa	0,23 %						

Data source: Goldman Sachs website, updated March 28, 2005.

In addition to the GSCI and its five subindices, the study utilises data on separate commodity futures that are included in the GSCI portfolio. The futures data consists of monthly observations of nearby futures contracts that are rolled forward during the five last trading days of the contract. Hence the data should be fairly comparable to that of the GSCI which is also rolled forward over a five-day period.

The equity data consists of the MSCI Europe Index. The original data set is USD-denominated and consists of daily closing prices. This has been then converted to euros and monthly returns have been calculated. The MSCI Europe Index portfolio consists of over 500 securities from 16 developed European markets: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Countries and securities within those countries are held in their capitalisation weights which are free float-adjusted.[35]

The bond data consists of monthly observations of the redemption yield on the 10-year German benchmark bond.

[35] Index specifications have been obtained from the website of MSCI (http://msci.com/equities) as of March 29, 2005.

5.2. Examination of the return characteristics

The empirical analysis of commodity returns is begun with an overview of the return characteristics of different commodities. First, the descriptive statistics of the five commodity classes are examined and compared with those of equities and bonds. The intra-asset correlation coefficients are estimated as well, including the correlations between the inflation rate and different asset classes.

Second, the correlations of commodities with stocks and bonds, as well as the inflation rate, are estimated across different investment horizons and business cycles. The examination of returns with different investment horizons might reveal patterns that might be veiled with relatively volatile monthly return data. Analysis of returns across business cycles aims instead to reveal potential counter-cyclicality of commodity with other asset classes, especially equities.

5.3. Performance measurement and asset allocation

As already mentioned in the opening paragraph of the chapter, the study concentrates on utilising two alternative performance metrics, the Stutzer index and the Omega measure, in the evaluation of asset performance and allocation decisions. These two metrics, including the underlying theories and the numerical estimation algorithms, will be discussed below on a fairly detailed level as their recognition and usage so far has been very limited. The conventional Sharpe ratio, which is used at the side of the two above mentioned metrics, is discussed more superficially, mainly to allow the reader to compare the underlying assumptions between the mean-variance framework and the distribution-free methods and their suitability to evaluate commodity returns.

5.3.1. The Sharpe ratio

The Sharpe ratio can be considered the most common measure of portfolio performance. It was first introduced by Sharpe in 1966 as a tool for evaluating and predicting the performance of mutual fund managers. Besides the Sharpe (1966) article, the measure was discussed in Sharpe (1975) and Sharpe (1994). The last of the three papers went beyond the discussion on the original measure providing more generality and covering a range of applications for the ratio. The Sharpe ratio is a simple reward-to-variability measure. Essentially, it scales the excess return of a given asset or portfolio with its standard deviation. Alternatively, the Sharpe ratio can be thought as a transformation of a simple t-test for equality in the means of two variables, the first being the time series of returns of a given portfolio and the second being the benchmark, most of the risk-free rate of return.

The ex-post[36] Sharpe ratio can formally be expressed as follows. Let R_{Pt} be the return on portfolio P at time t, R_{Bt} the return on a benchmark security, and D_t the excess return at time t:

$$D_t \equiv R_{Pt} - R_{Bt}. \tag{1}$$

Then denote the average value of D_t over the time period under examination with $\overline{D}$:

$$\overline{D} \equiv \frac{1}{T}\sum_{t=1}^{T} D_t, \tag{2}$$

and the standard deviation of returns over the time period with σ_D:

$$\sigma_D \equiv \sqrt{\frac{\sum_{t=1}^{T}\left(D_t - \overline{D}\right)^2}{T-1}}. \tag{3}$$

The ex-post Sharpe ratio S can then be written as

$$S \equiv \sqrt{\frac{\overline{D}}{\sigma_D}}. \tag{4}$$

The formulation of equation (4) is the one that is used throughout the study and referred to as "the Sharpe ratio". When the Sharpe ratio is used in the context of portfolio optimisation, the asset weights are those that maximise the Sharpe ratio of the portfolio the assets make up.

The Sharpe ratio is built on the assumptions of the mean variance paradigm. The most central, and at the same time the most restrictive, assumptions are that security returns are normally

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[36] In the 1994 paper, Sharpe distinguishes between ex-ante and ex-post ratios.

distributed, and that the mean and the variance of the return distribution are sufficient statistics to evaluate a portfolio. Keeping this in mind, we turn to look at the two alternative measures for the Sharpe ratio.

5.3.2. The Stutzer index

Stutzer (2000) introduces a distribution-free performance measure, the Stutzer index, which relies on a behavioural hypothesis. The logic of the metric is based on a simple assumption that investors are averse to earning a time-averaged portfolio return that is less than the average return of some designated benchmark. This benchmark can be e.g. risk-free rate of return, a broadly used benchmark index of a given asset class, or zero. When a portfolio is expected to earn a higher average return than the benchmark, the probability that it will generate below benchmark returns approaches zero at an exponential decay rate. The probability decay rate, later denoted with I_p, is then proposed as the new performance index.[37]

As discussed earlier in the paper, the Stutzer index has a behavioural foundation. According to the author, the behavioural hypothesis can be formulated as follows: a fund manager who is averse to receiving a non-positive time-averaged excess return above some specified benchmark will direct analysts to select a portfolio m that makes the probability of such a return occurring decay to zero at the maximum possible rate, I_m. The investors are hence simply assumed to minimise the probability that the excess returns will fail to be above a given threshold level over a long time horizon. The behavioural assumption of the Stutzer index is directly related to the "safety first" principle of Roy (1952), as noted by e.g. Bacmann and Pache (2004). The "safety first" principle advocates the maximisation of the probability of exceeding a minimum threshold level of return, as does the Stutzer index as well. The index can also be seen as a variant of the loss-aversion concept which states that investors have the tendency to be more sensitive to wealth reductions than to increases.

Denote a portfolio p's rate of return in excess of the benchmark in the time period t by R_{pt}, and denote the time-averaged excess return if earns over T periods by $\overline{R_{pT}}$ so that

[37] For an elaborate discussion on the theoretical foundation of the approach, see also Foster and Stutzer (2004).

$$\overline{R_{pT}} \equiv \frac{\sum_{t=1}^{T} R_{pt}}{T}. \tag{5}$$

Then assume that the portfolio has a positive expected excess return, following which the law of large numbers implies that $P(\overline{R_{pT}} \le 0) \to 0$ when $T \to \infty$. Further assume that the excess return process is individually and identically distributed (i.i.d.), and it can be shown that this probability will eventually converge to zero asymptotically at a computable exponential rate I_p, i.e.

$$P(\overline{R_{pT}} \le 0) \approx \frac{c}{\sqrt{T}} e^{-I_p T} \tag{6}$$

for large values of T, where c is a constant that depends on the return distribution.[38] The decay rate is then defined as the Stutzer index which can be defined as

$$I_p = -\lim_{T\to\infty} \frac{1}{T} \log\left[P\left(\overline{R_{pT}} \le 0\right)\right], \tag{7}$$

where $\overline{R_{pT}}$ is defined as in (5). The index value is hence negative in the case of positive expected excess returns and zero in cases of zero expected excess returns.

In his original article Stutzer follows the procedure presented by Bucklew (1990) and utilises Cramér's Theorem[39] to provide the following computation for the index I_p:

$$I_p = \max_{\theta}\left[-\log E\left(e^{\theta R_p}\right)\right] \tag{8}$$

for a portfolio denoted p with return R_p in excess of its benchmark. θ is a negative number representing the risk-aversion coefficient and E denotes the expected value operator. Bucklew (1990) shows how to compute the index of equation (8) in the special case when returns are normally distributed. In this case the result is half the squared Sharpe ratio.[40] This result yields

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[38] For more detailed documentation of the assumptions made on the returns and investor preferences see Stutzer (2000) and Fishburn (1977).

[39] See Cramér (1937)

[40] $I_p = \frac{1}{2}\lambda_p^2$. For a more detailed documentation see Stutzer (2000) and Bucklew (1990).

one of the desired characteristics of the Stutzer index discussed earlier in the paper, namely that in the case of normally distributed returns Stutzer index yields similar optimal asset weights, and ranks assets or portfolios in a similar order as the mean-variance analysis.

The case that is of interest in the framework of this study is the one when returns are not normally distributed. In this case the performance index I_p will depend on the higher order cumulants, or moments, of the return distribution as the function would reflect e.g. excess kurtosis or skewness. In his paper Stutzer rearranges the equation (8) in order to establish equivalence to the expected constant absolute risk aversion (CARA[41]) utility. The arrangement is written as follows:

$$-\frac{1}{e^{I_p}} = \max_{-c}\left[E(-e^{-cR_p})\right]. \tag{9}$$

The right hand side of equation (9) is the expected CARA utility of portfolio R_p with a positive, constant value for the risk aversion coefficient c. The left hand side of the equation (9) increases with I_p so the rank orderings of portfolios by the Stutzer index and the CARA utility are similar. Since the CARA utility has a positive third derivative, the rank order of the performance index will reflect skewness preferences, thus satisfying the desired properties of a performance measure discussed earlier in the paper.

In the case of normally distributed returns, the asset weights of an optimal portfolio, according to the Stutzer index, are similar to the ones obtained by the Sharpe ratio. In the context of this study, we are the most interested in the general case where returns do not follow normal distribution, or any other known distribution. In order to be able to compute the optimal asset weights that maximise the Stutzer index, we apply an algorithm presented by Stutzer (2000) which can be treated as an easy numerical maximisation problem. To construct the algorithm, let R_{it}, where $i = 0,\ldots,n$ and $t = 1,\ldots,T$, denote the time series of an asset i's returns in excess of a benchmark. At time t the weighted average of a portfolio's excess return can be written as $\sum_{i=0}^{n} w_i R_{it}$ where w_i is

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[41] CARA utility is a class of utility functions and it is also called exponential utility. The basic formulation for CARA utility function can be written $u(c) = -\left(\frac{1}{a}\right)e^{-ac}$, where $-ac$ is the elasticity of marginal utility and hence a is the constant positive coefficient of absolute risk aversion. CARA is related to the concept of constant *relative* risk aversion (CRRA).

the weight of the i^{th} asset. Since the portfolio weight w_0 is equal to $1-\sum_{i=1}^{n} w_i$, the excess return on the portfolio at time t can be rewritten as

$$R_{pt} = \sum_{i=1}^{n} w_i (R_{it} - R_{0t}) + R_{ot} \,. \tag{10}$$

The estimation for the right hand side of the equation (8), based on historical time series data, can be written as follows:

$$I_p = \max_{\theta} \left[-\log\left(\frac{1}{T} \sum_{t=1}^{T} e^{\theta R_{pt}} \right) \right]. \tag{11}$$

Substitution of the equation (10) into the equation (11) yields an algorithm which maximises the performance index (I_m). Hence the optimal asset weights are those $w_1 \ldots w_n$ that solve the following equation:

$$I_m = \max_{\theta, w_1, \ldots, w_n} \left[-\log \frac{1}{T} \sum_{t=1}^{T} e^{\theta \sum_{i=1}^{n} w_i (R_{it} - R_{0t}) + R_{0t}} \right]. \tag{12}$$

The equation (12) will be used in the numerical optimisation process for solving the optimal asset weights. The optimisation procedure of the Stutzer index is particular in the sense that the risk-aversion coefficient θ is determined simultaneously with the optimal portfolio weights. Hence, even if the Stutzer index has its links to the utility theories, no arbitrary risk-aversion coefficient needs to be defined.

5.3.3. The Omega measure

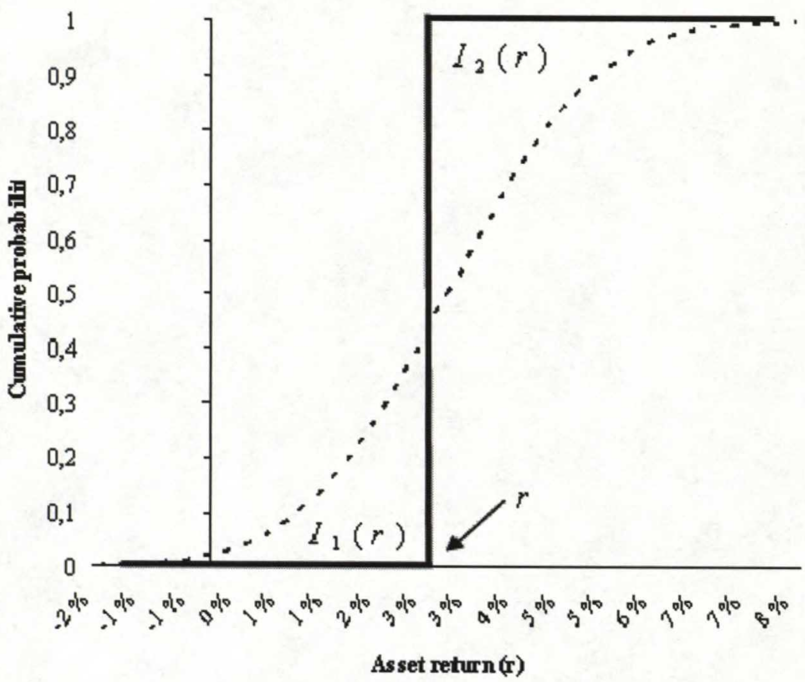
The Omega measure, introduced by Keating and Shadwick (2002), tackles the issue of measuring risk-adjusted performance of non-normal asset returns "in the spirit of the downside, lower partial moment and gain-loss literature". The essence of the measure is that it incorporates all of the higher moments of a given return distribution. The measure does not, however, estimate any individual moments but rather measures their total impact.

The content of the Omega measure is fairly simple. It splits the return space of a given asset into two subparts according to a threshold. The returns below the threshold are considered as losses while the returns above the threshold are gains. More specifically, the Omega measure provides a risk-reward measure for which the returns are weighted by their probability of occurrence. The Omega measure is thus a function of the threshold level and it is simply the probability weighted ratio of gains to losses relative as defined by the benchmark level. This can be formally written as follows:

$$\Omega(r) = \frac{I_2(r)}{I_1(r)}, \tag{13}$$

where $I_1(r) = \int_a^r F(x)dx$ and $I_2 = \int_r^b [1 - F(x)]dx$. F is the cumulative distribution function of the returns defined in the interval $[a, b]$ and r is the return level regarded as the loss threshold. The Omega function is essentially equivalent to the return distribution and hence all the higher moments of the distribution are included in the function. Omega is a smooth monotone decreasing function from $[a, b]$ to $[0, \infty]$, its value being equal to one when the threshold is chosen as the mean of the distribution, whatever the distribution. Figure 1 below illustrates the interpretation of the function graphically.

Figure 1: Graphical illustration of the Omega function



The figure illustrates graphically the Omega function of an asset with a given threshold level or return, r. The value of the Omega is $\Omega(r) = \dfrac{I_2(r)}{I_1(r)}$, where $I_1(r) = \int_a^r F(x)dx$ and $I_2 = \int_r^b [1 - F(x)]dx$ (a $\rightarrow$ 0, and b $\rightarrow \infty$). The integrals are depicted in the figure as the areas left between the cumulative distribution function (dashed line) and the return threshold r (solid line).

In practice the Omega function at a given threshold can be estimated as

$$\Omega(r) = \frac{\frac{1}{T}\sum_{t=1}^{T} \max(0, R_t - r)}{\frac{1}{T}\sum_{t=1}^{T} \left|\max(0, r - R_t)\right|}, \tag{14}$$

where R_t is the return on a given asset at time t, and r the chosen threshold return. The estimation of the equation (14) will be used in this study, and it has also been employed by Bacmann and Pache (2004) in the case of hedge funds. The same equation is also used in this paper to optimise asset weights in a portfolio. For this purpose, the Omega function can be written

$$\max_{w_1,\ldots,w_n} \Omega(r) = \frac{\frac{1}{T}\sum_{t=1}^{T}\max(0, R_{pt} - r)}{\frac{1}{T}\sum_{t=1}^{T}\left|\max(0, r - R_{pt})\right|}, \tag{15}$$

where $R_{pt} = \mathbf{w}'\mathbf{R}_t$, and w_n is the weight of the n^{th} asset.

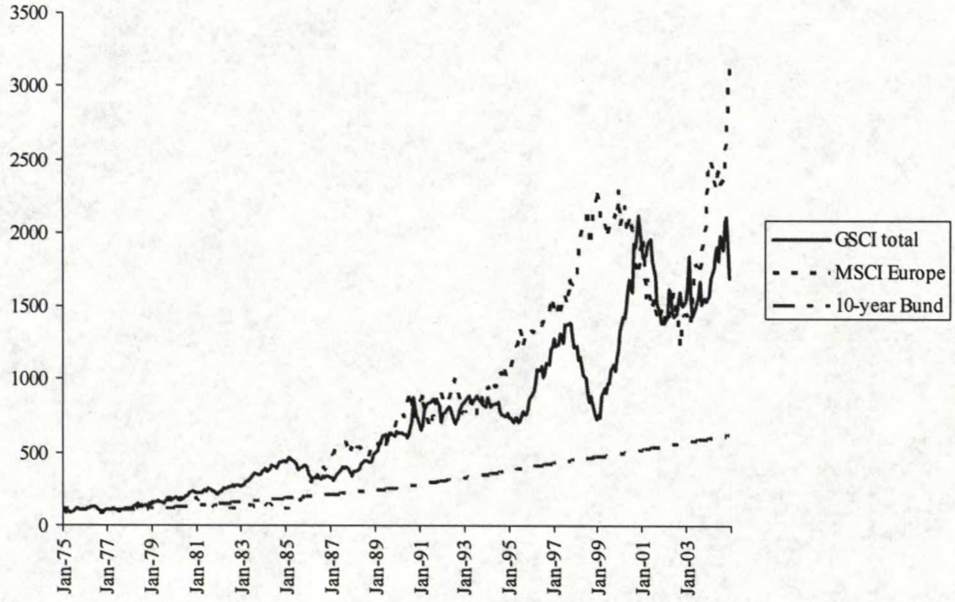
6. Empirical findings

This chapter presents the empirical results of the study. The chapter is divided into two subsections, the first making a general overview of the commodity returns in relation to other asset classes, and the second treating commodity futures as portfolio assets. The latter part is divided into two parts respectively. First, a stand-alone commodity portfolio is analysed in order to see how different classes of commodities behave when combined into a portfolio and whether a GSCI-type, production-based, weighting is near to an optimal allocation. Finally, the second part of the portfolio section treats commodities as a part of a diversified portfolio and assesses the diversification benefits available from commodity futures.

6.1. Characteristics of commodity returns

Let us begin the examination of commodity returns by making an overview of the relative performance of the asset class in relation to equities and bonds during the time period under examination. As the figure below indicates, commodities, represented by the GSCI composite index, have generated returns that are significantly higher than those of bonds and of roughly comparable level with equities. What is more, the correlation of commodity returns with equities seems to have been fairly low. However, the volatility of commodity returns seems to have been relatively high.

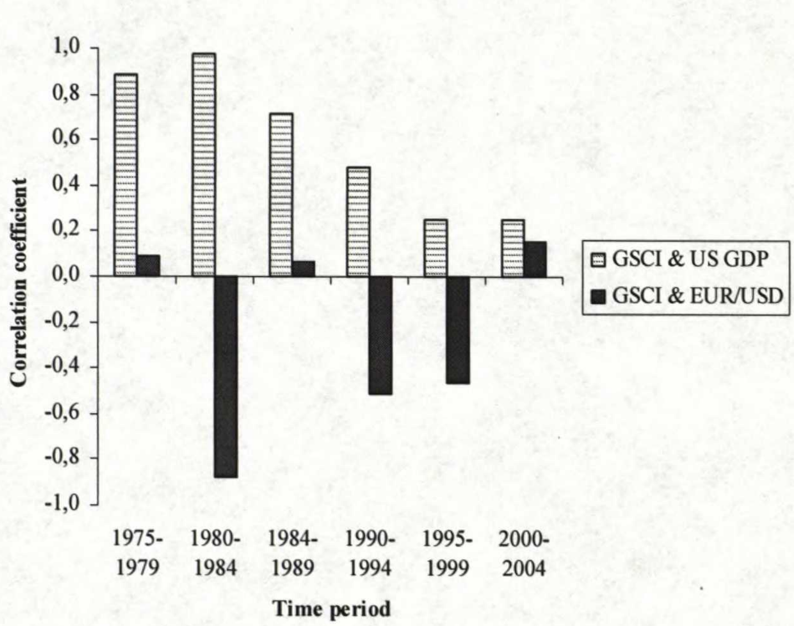
Figure 2: Relative performance of different asset classes 1975 - 2004



The figure illustrates the relative performance of commodities (GSCI total), equities (MSCI Europe), and bonds (German 10-year government bond) during the time period 1975 – 2004. Curves are indexed to 100 in January 1975.

The data consists of annualised monthly returns (observations from the last closing price of the month). All returns are euro-denominated. Source: Thomson Financial Datastream.

Figure 3: Correlation of the GSCI with the US GDP and the EUR/USD exchange rate



The data consists of monthly observations of the Goldman Sachs Commodity Index (GSCI) and the EUR/USD exchange rate, and quarterly observations of the US gross domestic product (GDP) during time period 1975 – 2004.

Source: Thomson Financial Datastream.

As one of the contributions of the study in hand is the viewpoint of a European investor with a euro-denominated portfolio, it would be worth our while to quickly check whether there exist strong correlations between the US gross domestic product and the EUR/USD exchange rate that has been used to transform the return data into euros. Figure 3 above illustrates the correlation coefficients of the US GDP and the exchange rate over five-year periods between 1975 and 2004. Based on the historical data, there clearly seems to have existed a positive correlation between the GSCI and the US GPD. However, the correlation has dramatically decreased, coefficient coming down from around 0.9 in the 1970s and 1980s to around 0.25 in the 1990s and 2000s. Unlike with the GDP figures, no clear relationship can be observed between the GSCI and the EUR/USD exchange rate. The correlation between the two has varied from negative to positive, the negative correlations having been stronger than the positive ones. Without digging deeper to the above-discussed relationships, we should keep in mind that the markets of US-traded commodity futures are subject to the influence of the cyclicality of the US economy. As will be later discussed, the cycles of the US and European economies can be significantly different. Hence, the behaviour of an investment portfolio consisting of European stocks and bonds, subject to changes in the European macroeconomic environment, may be markedly different from that of its US counterpart when considering an allocation to US-traded commodity futures.

A more detailed examination of the return profiles should allow us to get a better picture of the nature of commodity returns relative to the more traditional asset classes. As we can see from the Table 2 below, the return characteristics of commodities vary significantly across different types of commodities. During the period under examination, the returns of the overall GSCI index have been on average lower than equity returns, but higher than bond returns. The volatility of the overall GSCI, however, has been clearly lower than that of equities, which somewhat calls the common belief of commodity returns as a whole being extremely volatile into question. When examining the returns of given assets from an investor's viewpoint, we should not restrict to merely looking at the mean and variance of the return distribution. As discussed earlier in the paper, the higher moments of return distributions are of utmost importance when assessing the overall risk of an investment. Generally, a risk-averse investor should prefer return distributions with higher skewness and lower kurtosis. As Table 2 illustrates, commodities have in general exhibited positive, and equities negative, skewness. This seems to be well in line with the intuition derived from the earlier discussions in the paper. Livestock and precious metals have been the only classes of commodities whose return distributions have been negatively skewed, whereas industrial metals and agricultural products have exhibited significant positive skewness. As to the kurtosis of the returns, however, equities seem to have possessed a more favourable distribution profile than commodities as their kurtosis is notably lower. Yet another notion to take away from the below table is that the returns of the overall GSCI index are largely driven by its largest constituent, namely the energy futures.

Table 2: Return characteristics of different asset classes 1983 - 2004

	Energy	*Agri-cultural*	*Industrial metals*	*Livestock*	*Precious metals*	*GSCI total*	*MSCI Europe*	*10-year Bund*
Mean	10,91 %	-0,24 %	8,63 %	6,41 %	-0,67 %	8,38 %	14,70 %	6,22 %
Annualised volatility	31,72 %	19,00 %	23,46 %	19,57 %	20,02 %	19,01 %	22,63 %	0,46 %
Skewness	0,1084	0,3218	0,6215	-0,4928	-0,0866	0,0798	-0,2330	0,0557
Kurtosis	1,3157	0,7637	1,5899	0,9873	2,1483	0,9368	0,3733	-0,9717

The data consists of annualised monthly returns (observations from the last closing price of the month) during the period 1983 – 2004. All returns are euro-denominated. Kurtosis is excess kurtosis. GSCI stands for the Goldman Sachs Commodity Index.

Data source: Thomson Financial Datastream

As the study in hand views commodities from the viewpoint of portfolio diversification, examination of stand-alone returns is obviously not adequate. Table 3 reports the correlation coefficients across commodity sectors, equities, bonds, and the inflation rate. The examination has been restricted to begin from January 1983 i.e. since the inception of the energy sector data, in order to incorporate comparable time series data from all commodity classes. The first and foremost observation from the table is that all commodity classes have been negatively correlated with equity returns during the period 1983 - 2004. Correlations with bond returns have been very low, even negative in the case of precious metals. As to the question of whether commodities have the potential to act as an inflation hedge, the data does not seem to fully support the hypothesis. None of the individual commodity classes, excluding agricultural products, seem to have been positively correlated with the inflation rate. Finally, the intra-commodity correlations have all been positive, although of relatively low level, during the examination period. Obviously, the correlation coefficients are the lowest in the case of commodities that are fundamentally of very different nature, such as energy and industrial metals, or agricultural products.

Table 3: Correlations of commodities, bonds, equities, and inflation rate 1983 – 2004

	Energy	*Agri-cultural*	*Industrial metals*	*Livestock*	*Precious metals*	*GSCI total*	*MSCI Europe*	*10-year Bund*	*Inflation*
Energy	1								
Agricultural	0,1440	1							
Industrial metals	0,1079	0,2915	1						
Livestock	0,1739	0,4104	0,1630	1					
Precious metals	0,2228	0,3148	0,2895	0,2666	1				
GSCI total	0,9048	0,4157	0,2487	0,4155	0,3425	1			
MSCI Europe	-0,2188	-0,3580	-0,1180	-0,3468	-0,3054	-0,3427	1		
10-year Bund	0,0327	0,1196	0,0173	0,0944	-0,0668	0,0567	-0,0535	1	
Inflation	-0,0087	0,1315	-0,0258	0,0125	-0,0667	0,0055	-0,0204	0,8342	1

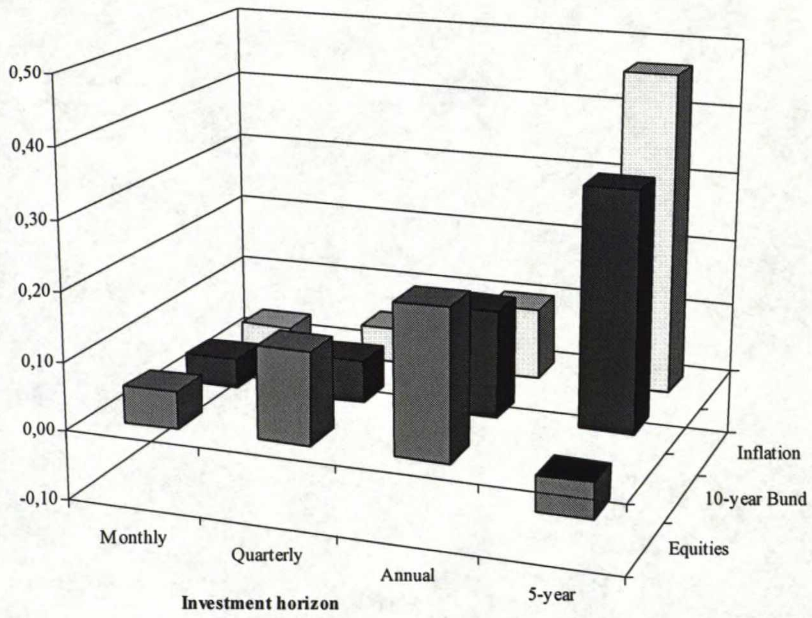
The data consists of annualised monthly returns (observations from the last closing price of the month) during the period 1983 – 2004. All returns are euro-denominated. GSCI stands for the Goldman Sachs Commodity Index.

Data source: Thomson Financial Datastream.

In order to gain deeper understanding of the return characteristics of commodities relative to other asset classes, we will next turn to looking at the returns and correlations in more detail. Here commodity markets are proxied by the GSCI composite index and no breakdown to different classes of commodities is made. This way we are able to extend the time period to be examined back to January 1975. The GSCI is a natural choice also due to its availability to investors in form of various instruments and its widespread use as a fund management benchmark representing the overall commodity market.

First, correlations of commodities with equities and bonds are computed using overlapping returns over monthly, quarterly, annual, and five-year time intervals. As the returns on commodities and equities are highly volatile, examination of correlations over longer holding periods may produce information that would otherwise have been concealed by short-term volatility.

Figure 4: Correlations of the GSCI at different investment horizons 1975 - 2004



The figure illustrates the correlation coefficients of the Goldman Sachs Commodity Index with other asset classes at different investment horizons that have been calculated using overlapping returns over monthly, quarterly, annual, and five-year time periods. The data consists of monthly observations during the period 1975 – 2004. All returns are euro-denominated.

Data source: Thomson Financial Datastream.

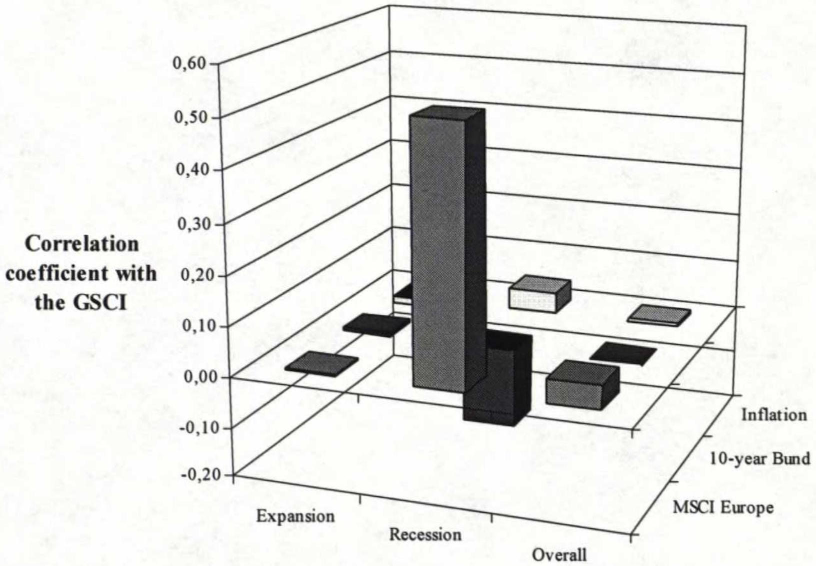
The findings reported in Figure 4 above give a somewhat mixed view of the cross-asset correlations. Correlation of commodities with equities and bonds increases rather similarly until one-year holding period. In the case of five-year horizon, however, the correlation with equities turns negative, whereas the correlation with bonds increases further. The ability of commodities to provide hedge against inflation clearly seems to improve as the holding period increases. Hence, it can be stated that except for bonds, the potential of commodities to offer diversification benefits seems to improve with longer investment horizons.

Second, we will turn into analysing asset returns across different phases of business cycles. This is done in order to gain understanding on whether commodities possess counter-cyclical properties in comparison to other asset classes. This kind of behaviour would be highly valuable in terms of portfolio diversification. By taking a look at the Panel A of the Figure 5, we can observe that the correlations of commodities with other asset classes indeed vary according to the phase of the business cycle. During recession, the correlation with bonds turns negative and the positive correlations with the inflation rate increases some, hence improving the performance of a given portfolio. The most striking, and also the most confusing, observation from Panel A is the abnormally high correlation between commodity and equity returns during periods of recession which would strongly contradict the ability of commodities to provide diversification benefits during recessions. Panel B illustrates the cyclicality of correlations in more detail as it differentiates between the early and late phases of business cycles[42]. The figure shows that the strong positive correlation of commodities and stocks during recessions has taken place during the early phases of recession.

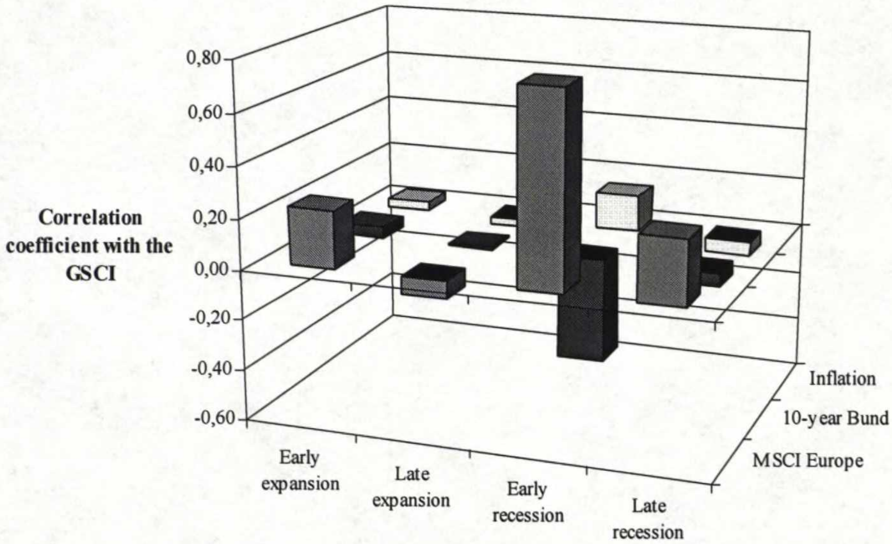
[42] The division into "early" and "late" expansions and recessions has been obtained by splitting the expansion and recession periods into two equally long subperiods.

Figure 5: Correlations of the GSCI across business cycles 1975 – 2000

Panel A



Panel B



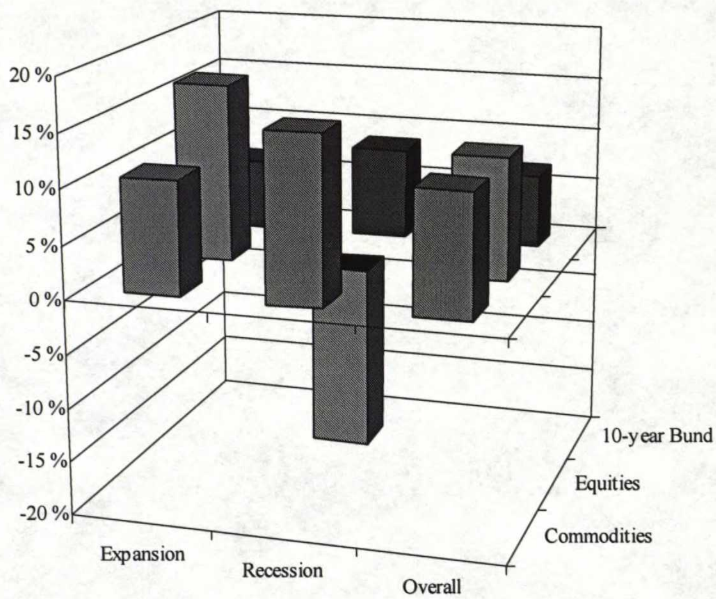
The return and inflation data consist of monthly observations during the period 1975 – 2000. Source for the business cycle information: The Business Cycle Dating Committee of the Centre for Economic Policy Research (CEPR). The division into "early" and "late" expansions and recessions in Panel B has been obtained by splitting the expansion and recession periods into two equally long subperiods. Data source: Thomson Financial Datastream.

Due to the fact that the recession periods have altogether spanned only over four years during the time period 1975 – 2000, the puzzling observations from the periods of early recession emerge from only two years of data. Hence, the correlation observations may suffer from randomly obscure coefficients during relatively short time periods. Thus, it makes sense to replenish the examination of cyclicality with asset-specific average returns over business cycles, reported in Figure 6. As we can observe from the figure, commodities have generated fairly steady returns over business cycles, the early expansion phases being the only periods with markedly lower returns. Equity returns have instead been significantly more sensitive to the cyclicality of the European economy, negative returns dating on average to the periods of recession. The cyclical return data would support the view that commodities do possess counter-cyclical features and that the diversification benefits should be pronounced during periods low economic growth. As most investors and portfolio managers are the most concerned of hedging against volatile equity returns, we further complement the picture with Figure 7 which illustrates the correlations of the GSCI during extreme equity returns. The data supports the counter-cyclical nature of commodities relative to equity returns, as the GSCI seems to be negatively correlated during extreme equity returns when the benefits of diversification are most needed. The inflation hedge and diversification effect towards bond returns, however, seems to have been relatively week during the periods of extreme equity returns. The findings presented in Figures 6 and 7 support the counter-cyclical nature of commodities and suggest that allocation of commodities into a portfolio consisting mainly of stocks and bonds should yield diversification benefits.

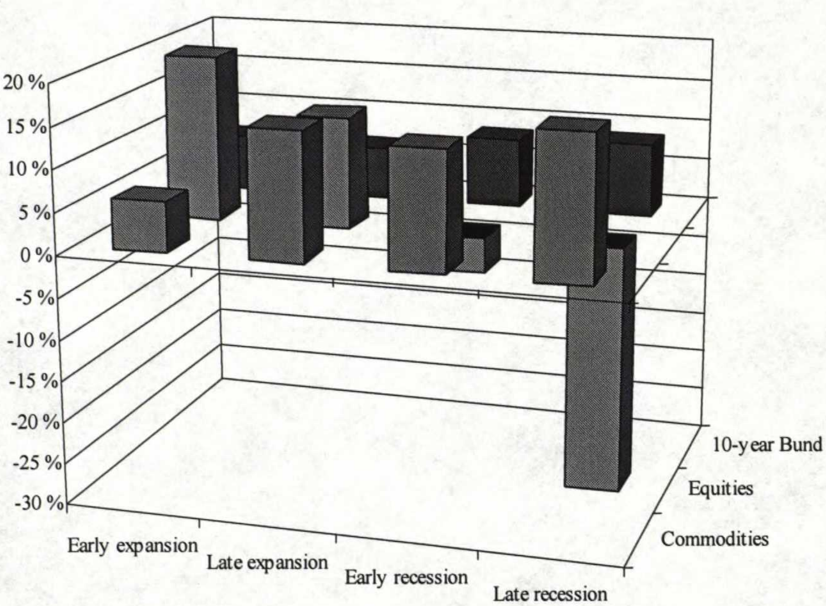
The above discussion highlights the profound differences in the way commodity and equity returns are determined. Stock prices, reflecting the discounted value of a firm's cash flows, are extremely volatile to changes in the expected future cash flows. Returns on commodity futures consist of both the changes in commodity spot prices and the roll returns. Hence, when the spot prices move or are expected to move, the entire forward curve of a given commodity should shift, the roll returns hence persisting. Moreover, even if changes in production conditions and inventory levels can make individual spot markets extremely volatile and subject to cyclicalities, the returns on holding a diversified portfolio of commodity futures that is periodically rolled forward can be fairly stable.

Figure 6: Returns of different asset classes across business cycles 1975 - 2000

Panel A

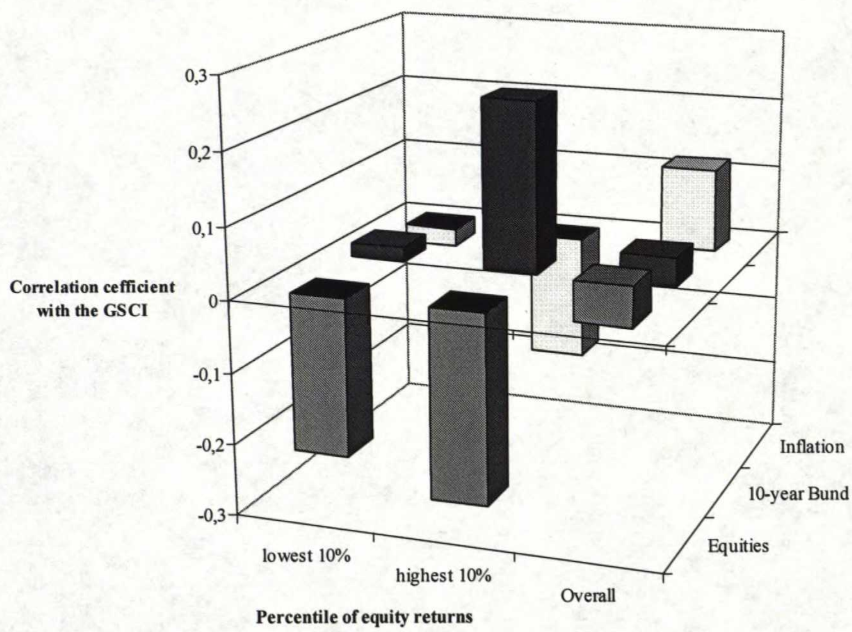


Panel B



The return and inflation data consists of monthly observations during the period 1975 – 2000. Source for the business cycle information: The Business Cycle Dating Committee of the Centre for Economic Policy Research (CEPR). The division into "early" and "late" expansions and recessions in Panel B has been obtained by splitting the expansion and recession periods into two equally long subperiods. Data source: Thomson Financial Datastream.

Figure 7: Correlations of the GSCI when equity returns at their lowest/highest



The data consists of monthly observations during the period 1975 – 2004.
Data source: Thomson Financial Datastream.

As the above analysis indicates, the historical data seems to support the hypothesis that commodities as an asset class have potential to offer diversification benefits for an investor whose portfolio consists mainly of traditional corporate securities. Correlations of commodities with stocks and bonds have historically been fairly low, or even negative in the case of equities. Furthermore, the hypothesis of commodities providing hedge against inflation seems to be supported by the data set, at least in the case of longer investment horizons. Most importantly, commodities seem to possess counter-cyclical properties, especially in comparison to equity returns. From a portfolio manager's viewpoint, this is especially valuable as the diversification benefits are the most needed during bear markets. Furthermore, the return distributions of most commodities have demonstrated positive skewness, contrary to equities whose return distributions have historically been negatively skewed. In addition to being favourable to a risk-averse investor, the positively skewed return distributions call for performance metrics that are able to incorporate the higher moments of the return distributions in the investment analysis. The excess kurtosis displayed by many commodities makes the utilisation of mean-variance framework in the case of commodities even more inappropriate.

As we are analysing the commodity investments from the viewpoint of a European investor, it is interesting to compare the results to the ones obtained by earlier, American studies. Return characteristics of commodities in the US market have been studied e.g. by Gorton and Rouwenhorst (2004), Schneeweiss et al. (2002), Kaplan and Lummer (1998), Jensen et al. (2000), and Ismailescu (2004). The correlations of commodity returns with equities seem to be largely following the same traits in Europe as in the US. The correlations with bonds, however, seem to be higher in Europe as in the US hence diluting the diversification benefits available from commodity investments. Direct comparison of the results is obviously somewhat deceptive as the time periods, reference indices etc. vary from study to study. The most interesting comparison of the results presented above can be made with those of Gorton and Rouwenhorst (2004) as they perform a cross-cyclical examination of US returns in a roughly similar manner to the paper in hand. The major difference in their results compared to the ones obtained here is that, from the US perspective, commodity returns seem to be more sensitive to changes in the business cycle, and that equity returns would reach bottom earlier in the cycle. The results obtained by Gorton and Rouwenhorst would imply that the diversification benefits from commodities are in US at their best in early recessions, when the equity returns have bottomed but commodities are still generating positive returns before hitting their lows in the late recession phase when equities have already recovered. The results obtained here would suggest that from the European viewpoint, the counter-cyclicality of commodities and stocks persists through the entire recession phase and peaks in its latter half. Furthermore, commodity returns have not been as sensitive to the cyclicality of the economy as in the US. Furthermore, it is extremely difficult, if not impossible, to differentiate between the impacts of the EUR/USD exchange rate, the effect of the US stock markets to the European ones, and the differences in the cyclicality of the economies[43], let alone the economic interplay of the above mentioned factors.

As a summation of the chapter, we should be fairly confident to state that commodities seem to possess favourable return characteristics in order to be efficiently utilised in portfolio diversification purposes by European investors. Hence, the first hypothesis made earlier in the

[43] See Appendix 5 for comparison of the European and US recessions.

paper is clearly supported by the empirical evidence. The data would suggest, however, that the conclusions obtained by American studies should not be directly applied to the asset allocation decisions of European purposes. Finally, the profile of the commodity data clearly reinforces the need to apply performance evaluation metrics other than the conventional mean-variance framework when dealing with commodity futures.

6.2. Commodities as a portfolio investment

Now that we have reviewed the essential characteristics of commodity returns and compared them with those of stocks and bonds, we turn into looking at commodities as a part of a diversified portfolio. First, however, we look at the commodity portfolio separately from other assets in order to gain understanding in how different commodity classes behave when combined into an overall commodity portfolio. This is done in order to find out what type of commodities are the most attractive for a financial investor and to evaluate whether a GSCI-type, production weighted overall index is actually the optimal vehicle to gain exposure to commodities. Second, commodities are allocated into a diversified portfolio containing stocks and bonds in order to answer the key research question: do commodities provide diversification benefits to a European portfolio investor. Moreover, we look at the size of a preferred commodity allocation.

6.2.1. Commodities in a stand-alone portfolio

Table 4 reports the results from eight optimisation exercises of a commodity portfolio. In addition to the conventional mean-variance optimisation i.e. the maximisation of the Sharpe ratio, both the Stutzer index and the Omega measure have been employed. The two alternative metrics have both been applied with different benchmarks in order to fully utilise the flexibility they allow as performance metrics. The chosen flat benchmarks have been selected zero, the average 12-month risk-free rate of return, and the average historical return of the Goldman Sachs Commodity Index. These should serve as sensible proxies for different types of return thresholds a commodity portfolio could be benchmarked against. In addition to the flat return thresholds, the Stutzer index optimisation has been run with a varying benchmark return, the 12-month risk-free rate. This way the optimisation is as close to the conventional Sharpe ratio -based approach as possible. This way we should be able to compare the results of a classic mean-variance optimisation to those obtained with a distribution-free method, the underlying assumptions being relatively similar.

Table 4: Optimisation of the commodity portfolio

Panel A reports the optimal asset weights of different commodity classes in diversified commodity portfolios. Optimisation is conducted using three different methods, namely the Sharpe ratio, the Stutzer index and the Omega measure. The Stutzer and Omega optimisations have been conducted using different return benchmarks. The weights of the ninth portfolio have not been obtained by optimisation but represent the composition of the Goldman Sachs commodity index as of March 2005.

Panel B reports the in-sample descriptive statistics of the respective portfolios.

Panel A: Optimal asset weights

Portfolio	1	2	3	4	5	6	7	8	9
Method	***Sharpe***			***Stutzer***			***Omega***		***GSCI***
Benchmark	*GER 12M (varying)*	*GER 12M (varying)*	*Zero*	*Ger 12M mean (flat 4,98%)*	*GSCI mean (flat 8,38%)*	*Zero*	*Ger 12M mean (flat 4,98%)*	*GSCI mean (flat 8,38%)*	-
Energy	40,80 %	40,81 %	22,29 %	40,78 %	96,17 %	27,11 %	49,23 %	97,55 %	74,63 %
Agricultural	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	11,04 %
Industrial metals	46,34 %	46,96 %	38,02 %	47,10 %	3,83 %	33,45 %	50,77 %	2,45 %	6,80 %
Livestock	12,86 %	12,22 %	39,69 %	12,12 %	0,00 %	39,44 %	0,00 %	0,00 %	5,68 %
Precious metals	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	1,86 %

Panel B: In-sample statistics of the above portfolios

Mean	9,28 %	9,29 %	8,26 %	9,29 %	10,83 %	8,37 %	9,75 %	10,86 %	8,38 %
Stdev	0,6314	0,6335	0,5199	0,6337	1,0605	0,5295	0,7075	1,0742	0,6658
Skewness	0,0301	0,0363	-0,0625	0,0376	0,1043	-0,1330	0,0872	0,1059	0,0798
Kurtosis	0,1049	0,0996	-0,2855	0,0975	1,3110	-0,1220	0,3016	0,1059	0,9368
Sharpe ratio	0,1469	0,1467	0,1588	0,1466	0,1021	0,1581	0,1379	0,1011	0,0510

The data consists of monthly annualised returns during the time period 1983 – 2004. Kurtosis is excess kurtosis. Data source: Thomson Financial Datastream. Graphs of the return distributions of the nine portfolios can be found in Appendix 6.

The most interesting observations from Table 4 are two-fold: those concerning the favourable allocation and those concerning the choice of the performance metric used in the allocation.

First, an attractive commodity portfolio can be constructed by allocating funds in only three types of commodities: energy, industrial metals, and livestock. Allocation to agricultural products and precious metals is not recommended by any performance metric. An important implication of this observation is that a production-weighted allocation of the GSCI would seem fairly sub-optimal. The findings would suggest that energy futures should serve as the backbone of a commodity portfolio. Energy futures, as documented earlier in the paper, have historically offered the highest returns, have a somewhat positively skewed distribution and are fairly weakly correlated with other commodity classes. The relative weights of the three commodity classes vary according to the return profile of the portfolio. The more aggressive the portfolio i.e. the higher the return and the greater the volatility, the larger is the allocation to energy futures and the larger part is invested to industrial metals instead of livestock futures.

Second, the choice of the performance metric used in the allocation does seem to matter. Especially the return level against which the portfolio is benchmarked affects the allocation. Logically, the higher the benchmark, the more aggressive is the allocation preferring energy futures to precious metals and livestock, and precious metals to livestock. An interesting observation is also the difference in allocation between the Stutzer index and the Omega measure when the same flat benchmarks are used. In the case of positive benchmarks, the Stutzer index clearly seems to allocate larger portion to livestock futures than the Omega measure. However, the in-sample descriptive statistics of the portfolios indicate that the profiles of the portfolios do not differ markedly. Finally, the allocation obtained by the Stutzer index using variable benchmark of 12-month risk-free rate is very similar to that obtained by the Sharpe ratio. This can be seen to be largely due to the return distribution of the overall portfolio that does not exhibit much of excess skewness or kurtosis. The allocation to industrial metals, showing positive skewness, is marginally larger with the Stutzer index but not large enough to significantly affect the return distribution of the overall portfolio.

6.2.2. Commodities in diversified portfolios

We now turn to the most interesting part of the empirical part of the study, namely assessing the diversification benefits from adding commodities into a portfolio consisting of stocks and bonds. The impact of commodity allocation is done by adding gradually (10, 20, and 30 percent allocations) commodities into portfolios the remainder of which consists of stocks and bonds with equal weightings. The weightings of different commodity classes have been optimised using the Stutzer index with a varying benchmark of 12-month risk-free rate. Employment of the index ensures that also the higher moments of the returns are incorporated in the examination. Furthermore, the variable 12-month risk-free rate can be considered the most neutral benchmark available for this purpose. Portfolio compositions are reported in Table 5. We will concentrate on analysing the first four portfolios, the rest four remaining as benchmark cases for the reader.

Table 5: Diversified portfolios with commodity allocations

Panel A: Portfolio compositions

Portfolio	*Energy*	*Agri-cultural*	*Industrial metals*	*Livestock*	*Precious metals*	*Commodi-ties total*	*Equities*	*Bonds*
1	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0 %	50,00 %	50,00 %
2	9,74 %	0,00 %	0,26 %	0,00 %	0,00 %	10 %	45,00 %	45,00 %
3	9,79 %	0,00 %	3,96 %	6,25 %	0,00 %	20 %	40,00 %	40,00 %
4	9,96 %	0,00 %	7,41 %	12,63 %	0,00 %	30 %	35,00 %	35,00 %
5	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0 %	75,00 %	25,00 %
6	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0 %	25,00 %	75,00 %
7	10,15 %	0,00 %	8,66 %	14,53 %	0,00 %	33 %	33,33 %	33,33 %
8	12,31 %	0,00 %	15,59 %	22,11 %	0,00 %	50 %	25,00 %	25,00 %

Commodity weights optimised with the Stutzer index, benchmarking to variable 12-month interest rate

Panel B: In-sample statistics of the above portfolios

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Mean	10,46 %	10,50 %	10,18 %	9,86 %	12,58 %	8,34 %	9,76 %	9,33 %
Stdev	38,88 %	34,27 %	29,70 %	26,46 %	58,35 %	19,43 %	25,81 %	26,42 %
Skewness	-0,2287	-0,1498	-0,2055	-0,2548	-0,2316	-0,2199	-0,2627	-0,2133
Kurtosis	0,3702	0,3371	0,4984	0,7884	0,3723	0,3639	0,8686	0,5663
Sharpe ratio	0,1408	0,1609	0,1749	0,1843	0,1302	0,1727	0,1851	0,1647

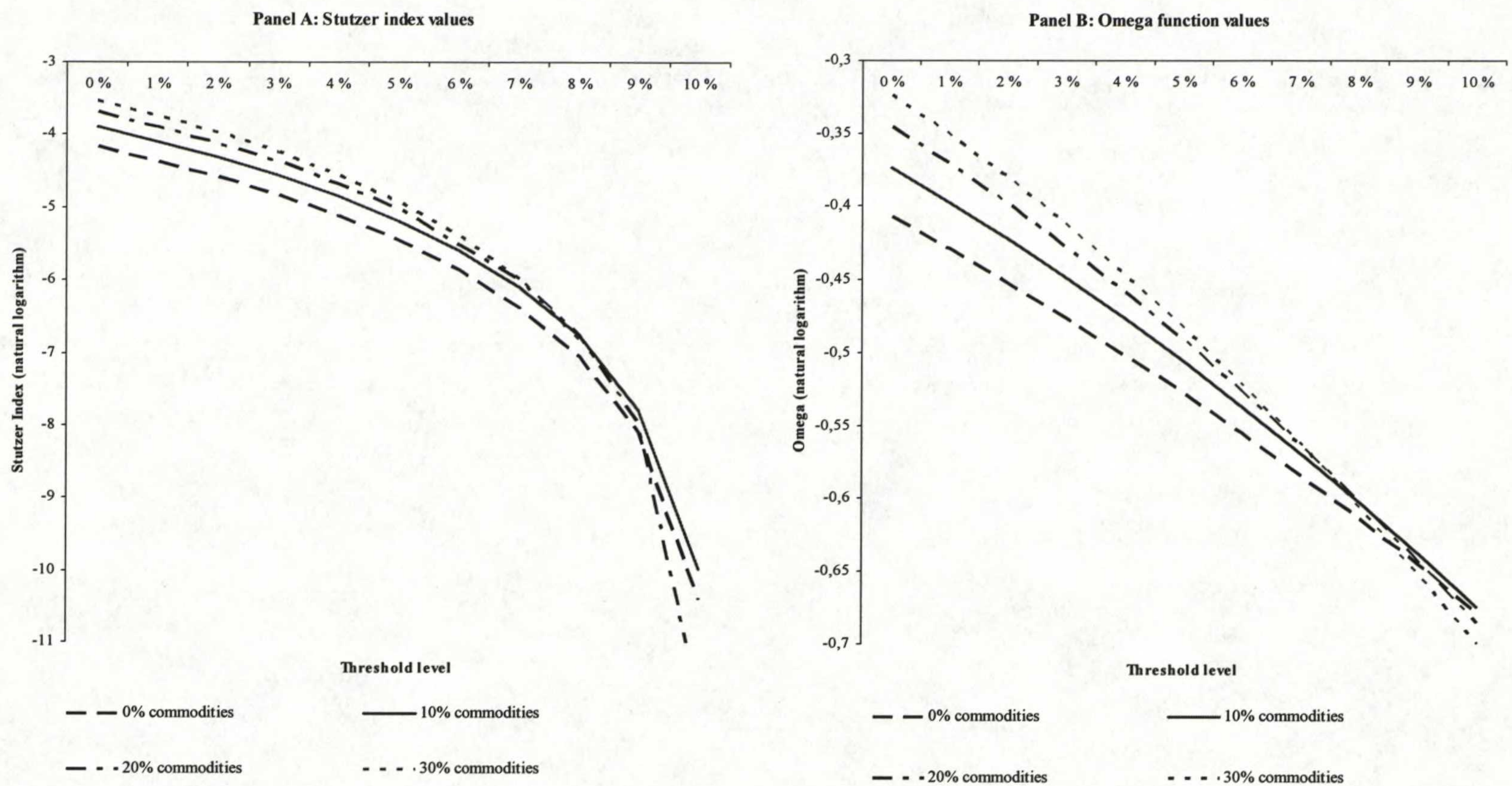
The table illustrates the effect of adding commodities in diversified portfolios. Panel A reports asset allocations and Panel B the descriptive statistics of the portfolios. The data consists of annualised monthly returns during the time period 1983 – 2004. All returns are euro-denominated. Kurtosis is excess kurtosis.

Data source: Thomson Financial Datastream.

Similarly to the stand-alone commodity portfolios, the commodity allocations consist of energy, industrial metal, and livestock futures. Agricultural products and precious metals receive no allocation. The in-sample descriptive statistics reported in Panel B of Table 5 clearly illustrate that already a very moderate allocation of commodities improved the return profile of a diversified portfolio. When comparing the statistics of the first and second portfolio, we can observe that already a 10% allocation of commodities clearly decreases portfolio volatility and increases the skewness of the return distribution. Furthermore, the small changes in the average return and the kurtosis of the return distribution both go to favourable direction. Incremental allocation of commodities, illustrated by the third and fourth portfolio, further reduces the portfolio volatility while the expected return suffers only a nominal decrease. Worth noting is, however, the decreased excess skewness of the portfolio returns. This results from the addition of livestock futures which have displayed fairly strong negative skewness. The diversification benefits of livestock futures stem from their strongly negative correlation with equities.

In addition to the static return data presented by Table 5, the diversification benefits of commodities were analysed with the Stutzer and Omega functions. As already mentioned earlier in the paper, a review of portfolio returns with the two performance metrics not only allows us to incorporate all moments of the return distributions in the examination, but also adds flexibility to the performance evaluation with the possibility to alter the threshold against which the returns are benchmarked. Figure 8 presents the values of the Stutzer index and the Omega function of the portfolios one to four. Panel A plots the Stutzer index values of the portfolios as a function of the threshold level against which the portfolio returns have been benchmarked. As discussed in Chapter 5.3.2., the interpretation of the Stutzer index is the maximum rate at which the probability of the portfolio earning less returns than the benchmark approaches zero. In other words, the higher the Stutzer index of a portfolio i.e. the higher is the curve of a portfolio plotted in the graph, the smaller are the chances that at some future date the returns on that portfolio will fall below the threshold level depicted on the X-axis. Panel B plots the values of the Omega function, respectively. To resume simply, the value of the Omega function of a portfolio is the ratio of the expected gains above a threshold level to the expected losses below that threshold level. In sum for both the two performance measures, the higher the position of the curve on the graph, the better is the risk-return profile of the portfolio at a given threshold level of return.

Figure 8: Stutzer and Omega function values of portfolios with commodities



In addition to commodities (allocation indicated in the legend) the portfolios contain equities (MSCI Europe index) and bonds (German 10-year government bond). Equities and bonds have equally large allocation in all of the portfolios. The allocation of different commodities has been executed with the Stutzer index benchmarking to variable 12-month risk-free rate of return. The higher the value of the two functions, the better the risk-adjusted performance of the portfolio. The data consists of annualised monthly returns during the time period 1983 – 2004. Data source: Thomson Financial Datastream.

Examination of the function values of the four portfolios in Figure 8 clearly backs up the claims for a commodity allocation in diversified portfolios. The curves of the portfolios containing commodities are plotted higher up in the graphs than the lowest dashed one representing the portfolio without any commodity allocation. This means higher Stutzer and Omega values at the respective levels of threshold returns and hence better risk-adjusted performance. An interesting observation is that up to threshold levels of around 8% p.a. the portfolio performance is the better the higher the allocation to commodities. This applies to both the two metrics. The incremental improvement resulting from an increase in the commodity allocation, however, decreases when moving forward along the X-axis and hence bringing up the threshold level of returns. At the 8% level of benchmark return, the lead of portfolios containing 20% or 30% commodities has disappeared completely in comparison to the portfolio with only 10% commodity allocation. The performance improvement of a 10% allocation persists throughout the array of benchmark returns. This implies that the desired diversification benefits are available already from a moderate allocation to commodities.

The incremental allocations to commodities seem to have resulted mostly in the reduced volatility of the portfolio, as can be observed from Table 5. When comparing the statistics of the second (10% commodities) and the fourth (30% commodities) portfolios, we can observe that the volatility has dropped markedly, from around 34% to 26%. This drop has been paired with only a marginal drop of mean return. The penalisation of a higher commodity allocation by the Stutzer and Omega functions at higher levels of benchmark returns can be explained with the decreased skewness and increased kurtosis of the portfolios with larger commodity allocations. This is due mostly to the inclusion of livestock futures that have displayed negative skewness, and industrial metal futures that bring along fairly high kurtosis. The two metrics hence capture the preference of risk-averse investors to upside deviations instead of downside ones, and even return distributions instead of peaked ones. Figure 8 illustrates then graphically how volatility reducing allocations that lower mean returns only marginally, embraced by increased Sharpe ratios, may cut the upside potential of the portfolio and make it more peaked. This is due to the higher moments of the return distribution evolving to less favourable direction, hence reducing the attractiveness of the portfolio from a more behavioural point of view. This notion, together with the distinctive return characteristics of commodities discovered earlier, further backs up the use of advanced performance metrics instead of the mean-variance framework when assessing commodity allocations.

As reported in Panel A of Table 5, the relative allocations to different commodity sectors are markedly different in the three commodity portfolios (portfolios 2 to 4). The total allocation to energy futures stays fairly stable, around 10% in all three portfolios. When the total amount of commodities is increased to 20% and 30%, the incremental allocations are done to industrial metals and livestock, according to the Stuzer index -based optimisation. Resuming the discussion in Chapter 6.2.1., it was found out that the higher the threshold levels against which stand-alone commodity portfolios were benchmarked, the higher was the relative allocation to energy futures at the cost of industrial metals and livestock. Hence, it could be argued that when targeting higher levels of benchmark returns, the commodity allocation should be tilted heavily towards energy futures in diversified portfolios as well. However, as discussed already in Chapters 2 and 3, large exposure to a single source of commodity risk, such as crude oil, might bring along certain risks. The investor would be vulnerable to price shocks, temporary changes in the term structures of futures prices, unexpected changes in correlations with other assets and inflation, etc. Hence, from the viewpoint of portfolio diversification, it would be advisable to diversify the commodity allocation to a few different commodity sectors, such as energy, industrial metals, and livestock that have stood out in the study.

6.3. Implications to asset allocation decisions

This section summarises the empirical findings made in the study, and discusses their implications to the portfolio allocation decisions of European financial investors. The chapter started off with an overview of the commodity returns and continued with an examination of commodities as portfolio assets. A few key observations stood out.

i) The return profiles of different classes of commodities vary substantially. The average returns, volatilities, as well as other descriptive statistics of the return distributions of different commodity classes share few common traits.

ii) The correlations of commodities with stocks and bonds have historically been very low or even negative, correlation coefficients varying from commodity class to another. The asset class as a whole seems to have possessed counter-cyclical properties, especially in comparison to equity returns.

iii) Commodities have historically been positively correlated with inflation hence enabling their use an inflation hedge. The degree of positive correlation, however, has been of moderate level and the highest with longer investment horizons.

iv) From a European perspective, commodities seem to have displayed roughly similar properties as the earlier US research has reported. However, differences seem to exist in the cyclicality of the returns and correlations, and the degree of the inflation hedge available.

v) An effective commodity allocation can be obtained with energy, industrial metal, and livestock futures.

vi) An allocation to commodities improves the risk-adjusted performance of a diversified portfolio consisting of stocks and bonds. The desired effect can be obtained already with a moderate 10% allocation to commodities.

The empirical results obtained in the study clearly back up the hypothesis of commodity investments being valuable in portfolio diversification purposes. From the viewpoint of a European financial investor, an allocation to commodities should improve the risk-adjusted performance of a diversified portfolio consisting mainly of stocks and bonds. The historical data used in the study suggests that already a moderate allocation to energy, industrial metal, and livestock futures improves the risk-adjusted portfolio performance and has the potential to smooth the cyclical variation of portfolio returns.

The empirical findings are based on analysing the Goldman Sachs commodity sector indices, the returns on which are based on holding a selection of the most important commodity futures. Hence, it would be interesting to know which particular commodities drive the returns of a given asset class available as an index vehicle based on the Goldman Sachs futures programmes. Table 6 below reports the correlations of the three recommended commodity sectors, represented by the

Goldman Sachs sector indices, and the most important underlying futures contracts. The time period spans the last 14 and half years of the examination period for which data on individual commodities is available, with the exception of gas oil. As we can observe from the table, the three cases seem to be fairly different. As to energy, all of the underlying commodities seem to have been highly correlated with the sector index. Hence, long positions in a single commodity, e.g. crude oil, would have replicated the performance of the sector strategy fairly well. The cases of industrial metals and livestock seem somewhat different. Even if there are certain commodities, such as copper and lean hogs, which seem to be correlated with the sector index clearly more than others, no single contract can be expected to closely replicate the returns of the respective index. Hence, there might be more significant diversification benefits available from industrial metals and livestock baskets than from energy. Similar conclusions can be drawn by looking at the correlation matrices of Appendix 2 and revisiting the discussion of Chapters 2 and 3. Finally, resuming again the discussion on the risk factors characteristic of commodity investments, it should be noted that diversification of a sector allocation to a few different commodity futures might prove rational. Too large an exposure to e.g. shifts in the term structure or correlations of a given commodity might result in abrupt shocks. Hence, from a diversification point of view, diversification of the commodity risk inside a given sector would be advisable as well.

Table 6: Correlation coefficients of selected commodity futures with GS sector indices

GS Energy		*GS Industrial metals*		*GS Livestock*	
WTI crude	0,93	*Aluminium*	0,04	*Live cattle*	0,09
Brent crude	0,91	*Copper*	0,69	*Feeder cattle*	0,02
Natural gas	0,90			*Lean hogs*	0,46
Unleaded gasoline	0,92				
Heating oil	0,92				
Gas oil	0,96				

The table reports the correlation coefficients of monthly observations of three commodity sector indices provided by Goldman Sachs with selected commodity futures contracts that are included in the indices. Time period under examination spans from April 1990 to December 2004, with the exception of Gas Oil for which data is available only from December 2003 onwards. Both the individual futures contracts as well as those underlying the indices are the next ones to expire and have been rolled forward monthly over a period of five days.

Data source: Commodity Research Bureau (CRB) for individual futures, Thomson Financial Datastream for the index data.

Worth noting is also the fact that commodity returns seem to have behaved in a somewhat different way from a European viewpoint than what the US studies have earlier been reported. An investor holding a Euro-denominated portfolio that is mostly exposed to European equities and bonds, should hence not draw direct conclusions from portfolio studies conducted with US-based data. The academic research of commodities as financial investments, however, is still so scarce that no solid stance on the issue can at the moment be taken. More empirical research, both amount and diversity-wise, on commodities as portfolio investments is needed in order to fully assess the potential of commodities as a diversification tool.

The above remark on the lack of empirical research applies especially to the performance evaluation and asset allocation metrics used in conjuction with commodities. Even if the non-normality of commodity returns has been widely reported, no appropriate performance measures have yet been proposed. The paper in hand presented and utilised two alternative performance metrics, namely the Stutzer index and the Omega measure that allow for non-normality of returns and provide flexibility in practical applications. Even if evaluation of performance metrics as such is not an objective of this study, the two measures proved useful and flexible to be used in the context of commodity investments. Hence, utilisation of these alternative performance metrics in the light of the research at hand is highly advisable to portfolio investors considering an allocation to commodity futures.

7. Summary and conclusions

This study has examined the use of commodity futures in portfolio diversification purposes. The main objective was to find out if an allocation to commodities improves the risk-adjusted performance of an investment portfolio consisting mainly of traditional corporate securities. Aware of the strong US bias of the preceding studies on commodity investments, and the practically non-existing use of performance metrics allowing for non-normality of returns so far, the paper in hand has taken the viewpoint of a European investor and utilised alternative performance metrics that acknowledge the special characteristics of commodity returns. Following a discussion on the theoretical foundation and earlier research concerning commodity investments, two hypotheses were made for the empirical part of the study. It was hypothesised that, from the viewpoint of a European investor, i) commodity returns have low or negative correlations with stocks and bonds and that they possess counter-cyclical properties with them, and that ii) inclusion of commodities into a portfolio consisting of stocks and bonds improves the risk-return profile of the portfolio.

It was found out that a broad, diversified commodity portfolio, proxied by the Goldman Sachs Commodity Index (GSCI), was correlated very weakly with equity and bond returns during 1975 – 2004. Furthermore, commodity returns were shown to have possessed counter-cyclical properties, especially when compared to equity returns. Counter-cyclicality is a particularly desirable property, as it provides protection against declining stock markets. A broad commodity portfolio was also found to have provided inflation hedge to some degree which, however, seemed to have realised the best with longer, five year, investment horizons.

Examination of commodities as portfolio assets was conducted in two phases. First, commodities, divided into sector-level subindices, were combined into a stand-alone portfolio. It was discovered that an optimal commodity portfolio can be assembled using energy, industrial metal, and livestock futures. The higher the threshold returns against which the portfolios were benchmarked i.e. the more aggressive the return profile, the more the allocation was tilted towards energy futures. Second, commodities were combined to a diversified portfolio with stocks and bonds. The relative allocation of different commodities persisted still: energy, combined with industrial metal and livestock futures, formed the backbone of the commodity allocation.

The most important finding of the study was that the risk-adjusted performance of a diversified portfolio, measured with the Stutzer index and the Omega measure, improved markedly when commodities were added. Already a moderate allocation of ten percent improved the risk-return profile of the portfolio throughout the array of threshold returns from zero to ten percent. A higher allocation further improved performance with lower thresholds. However, the additional improvement disappeared with threshold levels of around eight percent per annum and above.

In the light of the results obtained in the study, a moderate allocation to commodity futures seems highly advisable in portfolio diversification purposes. Already a ten percent allocation should provide the desired effect.[44] As to the composition of a commodity portfolio, energy and industrial metal futures should form the backbone, perhaps combined with livestock futures. In the case of energy futures, the underlying futures contracts were found to be highly correlated with each another, so e.g. a position in crude oil should proxy the sector performance fairly well. In the case of industrial metals and livestock, however, holding a portfolio of few different commodities might be sensible from the risk management point of view. Finally, a GSCI-type overall portfolio, long in all major commodity sectors and weighted by world production amounts, would seem a suboptimal choice to gain commodity exposure.

By concluding in favour of a commodity allocation to European portfolios, the study confirmed the suggestions already made in the US by Jensen et al. (2000), Jensen (2002), and Erb and Harvey (2005). They all studied commodity investments in a mean-variance framework and concluded that adding commodity futures into a diversified portfolio improves the risk-return profile of the portfolio. Gorton and Rouwenhorst (2004) have made a review of the return characteristics of commodities in relation to other asset classes in the US. When comparing their results to the ones obtained here, a few remarks can be made. First, there seem to be differences in the cyclicality of the returns. Second, the correlations of commodities with stocks and bonds seem to have been lower in the US than in Europe. Third, the ability of commodities to act as an

[44] Similar recommendations by investment professionals have recently appeared in the business press. For example, Kevin Norrish of Barclays Capital has suggested a 10-14% allocation of commodities in diversified portfolios (appeared in Kauppalehti, July 11, 2005). Mark Mathis of Dawny Day Quantum recommended a 5-10% allocation to balanced investment portfolios (appeared in the February 2005 issue of Risk magazine).

inflation hedge seems to have been a bit weaker in Europe than in the US.[45] Cyclicalities of returns are perhaps the single most important thing to be considered by a European investor when thinking an allocation to commodities. The recommendations made from the US perspective should not be taken on directly if the investor has exposure to European stock and bond markets, hence incorporating also the changes in the European macroeconomic environment. However, as the results of the study in hand demonstrate, commodity investments have historically possessed counter-cyclical properties with European equities as well, when looking at the level of strategic asset allocation.

It is also worth noting that the two alternative performance metrics used in the study, the Stutzer index and the Omega measure, proved useful in the context of commodity investments. Both the two metrics possess the desired theoretical properties of a valid performance measure. In addition, they can be applied to practice fairly easily. The most valuable properties of these metrics turned out to be the flexibility they allow for and their ability to incorporate such properties of return distributions that are not captured by the conventional mean-variance framework. So far this kind of alternative metrics have appeared only in the context of hedge funds, but based on the experience of this study, their usage with commodity investments is highly recommended.

This study was restricted to the level of strategic asset allocation. It took stance only to static asset allocation decisions. As to further research on the issue, the tactical level of commodity investing would be a highly interesting field to study. Now that we have established understanding on the feasibility of commodities to balance investment portfolios, domains such as term structures of different commodities, seasonalities, and timing of trades would be logical next steps to further analyse commodities as financial investments. These issues can be expected to be important factors in determining the success of commodity investments.

[45] Gorton and Rouwenhorst studied returns on an equally-weighted portfolio of commodity futures during the period 1959 – 2004. Hence, comparison of the results to the ones obtained in this paper should be made with reservations.

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9. Appendices

Appendix 1: Summary of the time series data used in the study

Item	*Data type*	*Time period available*
Goldman Sachs indices		
GSCI	Commodity futures index, long only, fully collateralised, world production weighted.	Jan 1970 - Dec 2004
GS Energy		Dec 1983 - Dec 2004
GS Agricultural		Jan 1970 - Dec 2004
GS Industrial metals		Jan 1977 - Dec 2004
GS Livestock		Jan 1970 - Dec 2004
GS Precious metals		Jan 1973 - Dec 2004
Commodity futures		
WTI crude oil	Nearby commodity futures contract, rolled forward during five last trading days.	Mar 1983 - Dec 2004
Brent crude oil		Jul 1987 - Dec 2004
Unleaded gasoline		Dec 1984 - Dec 2004
Heating oil		Nov 1978 - Dec 2004
Gas oil		Nov 2003 - Dec 2004
Natural gas		Apr 1990 - Dec 2004
Wheat -hard winter		Jan 1970 - Dec 2004
Wheat -soft red		Jul 1959 - Dec 2004
Corn		Jun 1959 - Dec 2004
Soybeans		Jun 1959 - Dec 2004
Cocoa		Jun 1959 - Dec 2004
Cotton		Jun 1959 - Dec 2004
Coffee		Aug 1972 - Dec 2004
Sugar		Jan 1961 - Dec 2004
Aluminium		Jan 1983 - Dec 2004
Copper		Jun 1959 - Dec 2004
Feeder cattle		Noc 1971 - Dec 2004
Live cattle		Nov 1964 - Dec 2004
Lean hogs		Feb 1966 - Dec 2004
Gold		Dec 1974 - Dec 2004
Silver		Jun 1963 - Dec 2004
MSCI Europe	Equity index, total return	June 1974 - Dec 2004
German 10-year government bond	Bond redemption yield	April 1977 - Dec 2004
German 12-month euro/mark interest rate	Risk-free interest rate	Jan 1975 - Dec 2004
EU inflation rate	Consumer price index	Jan 1961 - Dec 2004
US gross domestic product		Q1 1947 - Q4 2004
EUR/USD exchange rate		Jan 1975 - Dec 2004

Observations made monthly, except for the US GDP data which comes in quarterly intervals.

Commodity futures data provided by the Commodity Research Bureau, other data obtained from the Thomson Financial Datastream.

Appendix 2: Correlations of selected individual futures contracts

Panel A: 1975-1979

	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	N/A	1,00									
Wheat	N/A	N/A	1,00								
Coffee	N/A	N/A	**-0,42**	1,00							
Sugar	N/A	N/A	**0,49**	**-0,57**	1,00						
Aluminium	N/A	N/A	N/A	N/A	N/A	1,00					
Copper	N/A	N/A	**0,51**	**0,27**	**-0,09**	N/A	1,00				
Live cattle	N/A	N/A	**0,44**	**0,05**	**-0,23**	N/A	**0,79**	1,00			
Lean hogs	N/A	N/A	**0,20**	**-0,50**	**0,05**	N/A	**-0,16**	**0,19**	1,00		
Gold	N/A	N/A	**0,56**	**0,16**	**0,05**	N/A	**0,81**	**0,78**	**-0,13**	1,00	
Silver	N/A	N/A	**0,52**	**0,20**	**0,07**	N/A	**0,76**	**0,60**	**-0,18**	**0,92**	1,00

Panel B: 1980-1984

	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	N/A	1,00									
Wheat	N/A	N/A	1,00								
Coffee	N/A	N/A	**-0,20**	1,00							
Sugar	N/A	N/A	**0,82**	**0,10**	1,00						
Aluminium	N/A	N/A	**0,17**	**0,29**	**0,98**	1,00					
Copper	N/A	N/A	**0,69**	**0,21**	**0,77**	**0,82**	1,00				
Live cattle	N/A	N/A	**0,23**	**0,00**	**0,28**	**0,67**	**0,26**	1,00			
Lean hogs	N/A	N/A	**-0,30**	**-0,47**	**-0,49**	**0,07**	**-0,55**	**0,04**	1,00		
Gold	N/A	N/A	**0,75**	**0,11**	**0,88**	**0,84**	**0,87**	**0,19**	**-0,45**	1,00	
Silver	N/A	N/A	**0,53**	**0,25**	**0,63**	**0,84**	**0,90**	**0,16**	**-0,47**	**0,84**	1,00

Panel C: 1984-1989

	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	N/A	1,00									
Wheat	**0,58**	N/A	1,00								
Coffee	**-0,33**	N/A	**-0,35**	1,00							
Sugar	**-0,57**	N/A	**0,69**	**-0,45**	1,00						
Aluminium	**-0,91**	N/A	**0,54**	**-0,39**	**0,65**	1,00					
Copper	**-0,54**	N/A	**0,78**	**-0,45**	**0,78**	**0,75**	1,00				
Live cattle	**0,82**	N/A	**0,75**	**-0,57**	**0,69**	**0,69**	**0,76**	1,00			
Lean hogs	**0,56**	N/A	**-0,48**	**0,01**	**-0,25**	**-0,25**	**-0,41**	**-0,20**	1,00		
Gold	**0,67**	N/A	**-0,11**	**-0,39**	**0,30**	**0,62**	**0,37**	**0,33**	**0,12**	1,00	
Silver	**0,13**	N/A	**-0,20**	**-0,25**	**-0,29**	**0,27**	**-0,04**	**0,05**	**0,10**	**0,56**	1,00

Panel D: 1990-1994

	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	**0,05**	1,00									
Wheat	**-0,49**	**-0,09**	1,00								
Coffee	**-0,09**	**-0,09**	**0,21**	1,00							
Sugar	**-0,24**	**0,14**	**0,30**	**0,44**	1,00						
Aluminium	**0,57**	**-0,34**	**-0,43**	**-0,46**	**-0,24**	1,00					
Copper	**0,42**	**-0,39**	**-0,04**	**0,48**	**0,32**	**0,32**	1,00				
Live cattle	**0,30**	**-0,05**	**-0,29**	**-0,56**	**-0,25**	**0,56**	**-0,07**	1,00			
Lean hogs	**0,14**	**-0,12**	**-0,56**	**-0,28**	**0,12**	**0,46**	**-0,04**	**0,30**	1,00		
Gold	**0,10**	**0,24**	**-0,08**	**0,47**	**0,48**	**-0,25**	**0,16**	**-0,18**	**0,08**	1,00	
Silver	**-0,29**	**0,19**	**0,21**	**0,58**	**0,68**	**-0,51**	**0,09**	**-0,41**	**0,07**	**0,79**	1,00

Panel E: 1995-1999

	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	**0,48**	1,00									
Wheat	**0,25**	**-0,01**	1,00								
Coffee	**0,07**	**-0,18**	**0,06**	1,00							
Sugar	**0,25**	**-0,10**	**0,58**	**0,52**	1,00						
Aluminium	**0,33**	**0,28**	**-0,41**	**-0,34**	**-0,57**	1,00					
Copper	**0,31**	**-0,31**	**0,69**	**0,36**	**0,73**	**-0,33**	1,00				
Live cattle	**0,41**	**0,03**	**-0,04**	**0,15**	**0,29**	**0,10**	**0,16**	1,00			
Lean hogs	**0,60**	**0,22**	**0,64**	**0,42**	**0,54**	**-0,32**	**0,53**	**0,17**	1,00		
Gold	**0,34**	**-0,19**	**0,84**	**0,17**	**0,74**	**-0,47**	**0,86**	**0,16**	**0,62**	1,00	
Silver	**-0,27**	**-0,03**	**-0,06**	**-0,18**	**-0,14**	**0,04**	**-0,21**	**-0,18**	**-0,26**	**-0,15**	1,00

Panel F: 2000-2004

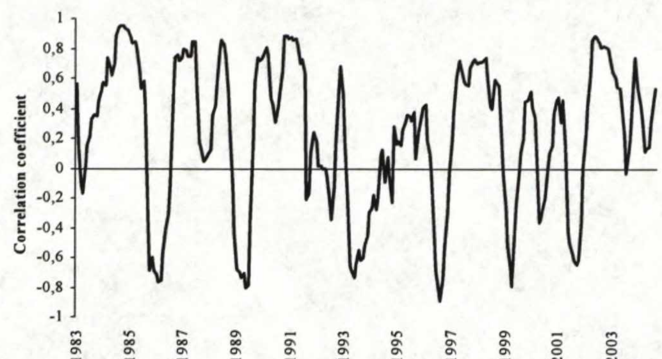
	Brent	*Nat .gas*	*Wheat*	*Coffee*	*Sugar*	*Aluminium*	*Copper*	*Live cattle*	*Lean hogs*	*Gold*	*Silver*
Brent	1,00										
Nat .gas	**0,65**	1,00									
Wheat	**0,27**	**0,33**	1,00								
Coffee	**0,46**	**0,25**	**-0,06**	1,00							
Sugar	**0,32**	**0,43**	**-0,16**	**0,18**	1,00						
Aluminium	**0,77**	**0,53**	**0,07**	**0,68**	**0,30**	1,00					
Copper	**0,84**	**0,59**	**0,27**	**0,51**	**0,16**	**0,91**	1,00				
Live cattle	**0,56**	**0,55**	**0,37**	**0,20**	**0,08**	**0,53**	**0,62**	1,00			
Lean hogs	**0,48**	**0,29**	**-0,26**	**0,48**	**0,30**	**0,64**	**0,58**	**0,38**	1,00		
Gold	**0,69**	**0,54**	**0,53**	**0,19**	**-0,20**	**0,53**	**0,77**	**0,69**	**0,25**	1,00	
Silver	**0,79**	**0,51**	**0,30**	**0,50**	**0,01**	**0,83**	**0,94**	**0,55**	**0,49**	**0,81**	1,00

The data consists of monthly quotes of selected individual futures contracts. The quotes are those of the next contract to expire, and the positions are rolled forward monthly during the five last trading days of the month. The five-day rolling period should make the data comparable to the futures positions underlying the Goldman Sachs Commodity Index that are rolled forward during a five-day period as well.

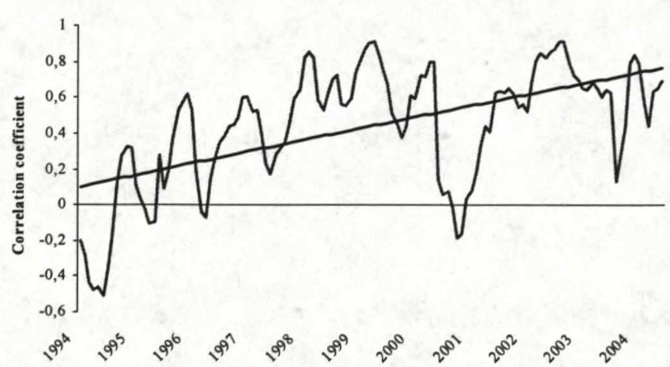
Source: The Commodity Research Bureau (CRB).

Appendix 3: Case examples of varying intra-commodity correlations

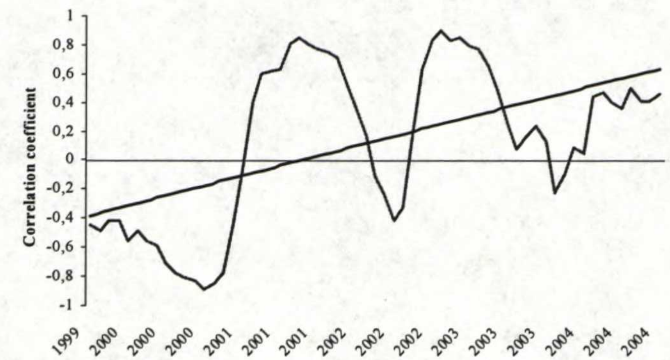
Panel A:
Correlation between crude oil (WTI) and gold
1983 - 2004



Panel B:
Correlation between crude oil (WTI) and natural gas
1994 - 2004



Panel C:
Correlation between coffee and sugar
2000 - 2004



Panel A, illustrating the correlation between WTI crude oil and gold futures during the time period between 1983 and 2004, gives a case example of a pair of seemingly unrelated commodities whose correlation has varied dramatically over time.

Panels B and C give two examples of pairs of commodity futures inside the same class of commodities (energy and agricultural products) that have exhibited a trend-like increase in their mutual correlation.

The above case examples illustrate how challenging the risk budgeting of a commodity futures portfolio can be. The overall risk of e.g. an agricultural portfolio with fixed weightings may increase substantially with the underlying futures becoming increasingly correlated. Moreover, the aggressive changes between correlations of unrelated commodities pose a major challenge for a portfolio manager.

(The data consists of monthly quotes of selected individual futures contracts. The quotes are those of the next contract to expire, and the positions are rolled forward monthly during the five last trading days of the month.)

Data source: The Commodity Research Bureau (CRB).

Appendix 4: The CEPR business cycle dating

"The Centre for Economic Policy Research has formed a committee to set the dates of the euro area business cycle. Its mission is to establish the chronology of recessions and expansions of the 11 original euro area member countries plus Greece for 1970-1998 and of the euro area as a whole from 1999 onwards. The euro area currently includes Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain.

In determining the chronology of the euro area business cycle, the CEPR Business Cycle Dating Committee has decided to adopt a definition of a recession similar to that used by the National Bureau of Economic Research (NBER), which has for many years dated the US business cycle. We have had to adapt the NBER definition, however, to reflect specific features of the euro area. Thus the Committee defines a recession as a significant decline in the level of economic activity, spread across the economy of the euro area, usually visible in two or more consecutive quarters of negative growth in GDP, employment and other measures of aggregate economic activity for the euro area as a whole, and reflecting similar developments in most countries. A recession begins just after the economy reaches a peak of activity and ends when the economy reaches its trough. Between trough and peak, the economy is formally in an expansion; between peak and trough it is in a recession. In both cases, growth rates may be very low.

The CEPR Committee's task is significantly different from that of the NBER. The euro area groups together a set of different countries. Although subject to a common monetary policy since 1999, they even now have heterogeneous institutions and policies. Moreover, European statistics are of uneven quality, long time series are not available, and data definitions differ across countries and sources."

...

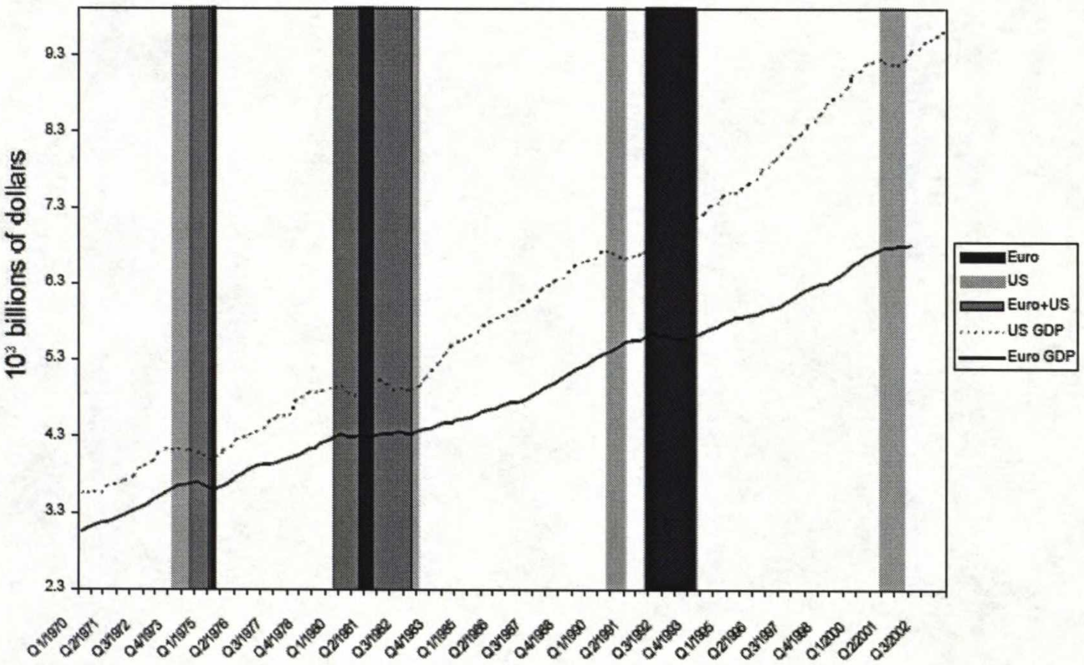
"The Committee has identified the following cyclical episodes since 1970, with peaks and troughs dated as follows:

PEAK	TROUGH
1974 Q3	1975 Q1
1980 Q1	1982 Q3
1992 Q1	1993 Q3

Thus the Committee has identified three recessions: 1974 Q3 to 1975 Q1, 1980 Q1 to 1982 Q3, and 1992 Q1 to 1993 Q3."

Source: The Centre for Economic Policy Research

Appendix 5: European and US Recessions 1970 - 2002

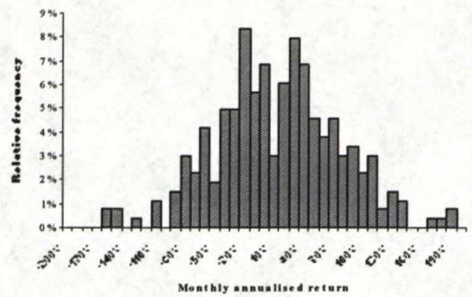


The above figure illustrates the differences in the timing of US and European business cycles. The dashed curve illustrates the evolution of the US GDP, the solid curve the European one. Time periods shaded with grey illustrate US recessions, and black shading the European recessions, respectively. Dark grey shadings with black borders show time periods when a recession has occurred at the same time in Europe and the US.

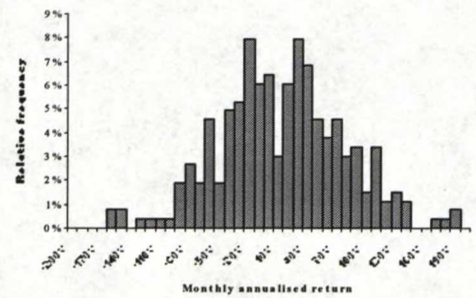
Source: The Business Cycle Dating Committee of the Centre for Economic Policy Research (CEPR)

Appendix 6: Return distributions of the stand-alone commodity portfolios

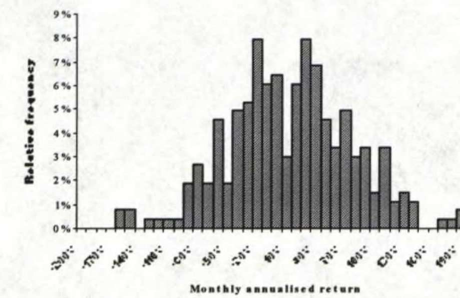
Portfolio 1



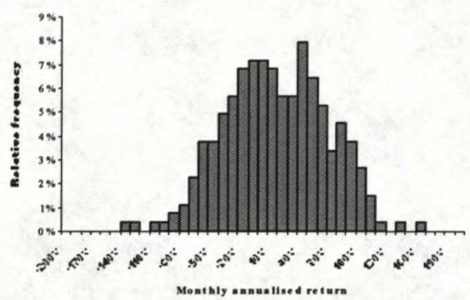
Portfolio 2



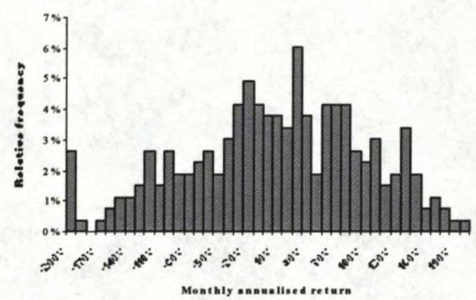
Portfolio 3



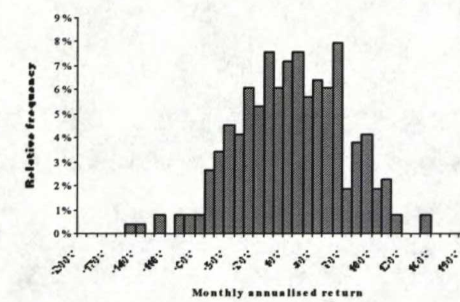
Portfolio 4



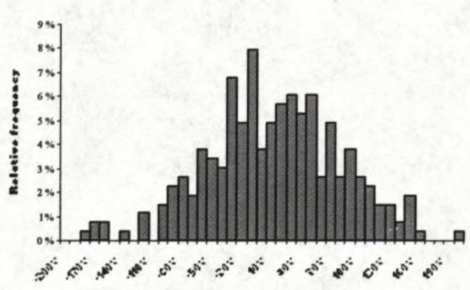
Portfolio 5



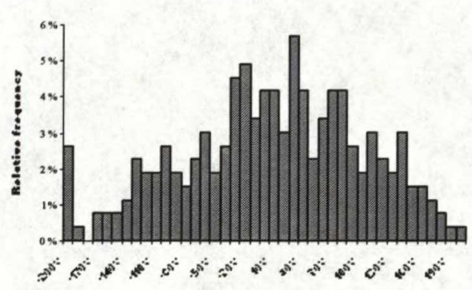
Portfolio 6



Portfolio 7



Portfolio 8



Portfolio 9